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By Peggy Malnati
A few months ago, in this space, I wondered if and how composites might migrate more aggressively into automotive structures. And I promised to look into the matter and report back. Here’s what I found.

First, a refresher on my premise: Being a supplier to the automotive industry is not easy. Auto OEMs demand both high-volume manufacturing and high part quality. Parts and process must be qualified, and process must be sufficiently controlled so as to produce parts that consistently meet specification. A supplier might be expected to invest in capital equipment up front, and might not see revenue for a given part until several months after production has begun. Parts must be delivered on time, every time, and likely will be part of a just-in-time (JIT) system. Suppliers are expected to discover, continuously, new cost savings to help the automaker reduce expenses. Not for the faint of heart.

In the composites industry today, there are few companies that have sufficient experience in the automotive supply chain to meet these demands. The composites industry comprises, for the most part, disparate, relatively small firms. Most of the “large” fabricators in the composites industry primarily serve the aerospace market, where process, quality and volume paradigms are wholly different than they are in automotive. Those composites fabricators who are involved in auto parts production have, traditionally, served OEMs of high-end sports cars and racecars, where volumes are similarly low and, significantly, margins are high.

Still, it appears that composites’ time in high-volume automotive manufacturing has come. Fuel efficiency standards in the U.S. and CO₂ emissions standards in Europe are driving automotive OEMs toward lightweighting like never before. So, my question is this: If this means composites’ time has come in automotive, how can the composites industry meet the needs of the automotive supply chain?

BMW is already modeling for the world one option. Its all-electric i3 passenger car, which features a first-of-its-kind carbon fiber passenger cell (body-in-white), is being manufactured with almost no help from the rank-and-file composites community. BMW either owns jointly or wholly the entire composites material and manufacturing supply chain, from carbon fiber precursor production in Japan to carbon fiber manufacturing in Washington State to fabric weaving, preforming and resin transfer molding (RTM) in Germany. It’s unlikely, however, that every OEM interested in increasing the use of composites in its cars will follow BMW’s lead. And if this is true, what are the options?

Eugenio Toccalino, global strategic marketing director for Dow Automotive Systems (Auburn Hills, Mich.), says the auto industry is in the early stages of substantial composites integration, in which each OEM is pursuing a different strategy. “BMW did it on their own because they were first,” he contends. “It was a way for an OEM to build competitive advantage. There will be a democratization of technology — it will spread and be outsourced more.”

Steven Henderson, president of Dow Automotive Systems, notes, “We have OEMs who are dipping their toe in, and those who are all in.” The automotive supply chain, he says, must develop a mix of carbon fiber- and metals-based solutions to meet needs that range from structural to aesthetic. Whatever role composites play, Henderson and Toccalino agree that the auto industry requires two things: Fast-cure resins and composites manufacturing systems that can be easily and directly integrated into the body shop.

How might composites enter the body shop? Henderson and Toccalino argue that existing Tier 1 automotive suppliers are key, and they will have to develop
more composites material and manufacturing expertise, either organically or by acquisition. “The economies of scale in automotive manufacturing are too large and the capital resources required are too big,” says Toccalino of the necessity for Tier 1s to be a part of the composites solution. “The Tier 1s are already in the supply chain and have the relationships, and know what automakers want.”

“We have already been lobbied by several tier suppliers to help them improve their composites manufacturing knowledge,” says Henderson. Dow is a party to at least one partnership, with Ford and a Tier 1, to develop carbon fiber composite structures. Such partnerships, he says, could become more common.

So, who are the big Tiers that might or might not come knocking on the composites industry’s door in search of greater knowledge? They include Faurecia (Nanterre, France), Magna (Aurora, Ontario, Canada), Continental Structural Plastics (CSP, Auburn Hills, Mich.), Bosch (Gerlingen-Schillerhöhe, Germany), Denso (Kariya, Aichi, Japan), Aisin (Kariya, Aichi, Japan), Hyundai Mobis (Seoul, Korea), ZF AG (Friedrichshafen, Germany) and Johnson Controls (JCI, Milwaukee, Wis.). Many of them already have at least some composites expertise — and some, like CSP, have a long history in composites manufacturing, particularly with sheet molding compound (SMC).

Dr. Mike Siwajek, director of R&D at CSP, says, “We’ve been pushed by the OEMs into high-volume applications,” pointing to CSP’s manufacture of an SMC roof for Jeep that approaches volumes in excess of 100,000 units annually. CSP, he says, is looking at two processing technologies to expand automotive penetration: compression molding of carbon-fiber SMC and resin transfer molding (RTM).

Probir Guha, VP of advanced R&D at CSP, sees automotive OEMs taking a more active role in composites development, seeking partners up and down the supply chain to help bring ideas to market quickly. CSP, he says, is involved in several development partnerships right now — news of which is expected soon. What’s more, the global nature of automaking puts additional demands on those in the supply chain: “Whatever you can do here,” he points out, “you must be able to do in Europe and China as well.”

Where, then, does this leave those elsewhere in the composites industry who want to be a part of the automotive composites emergence, but are neither tier suppliers nor manufacturers of a fast-cure resin or novel fiber form? For lessons, we might look to the plastics industry — traditional thermoplastics molding, that is. Injection molding, for example, is, in many ways, a manufacturing process ready-made for the automotive supply chain. When properly setup and run, an injection molding process requires little or no operator involvement, offers a relatively short cycle time, provides good process control, has minimal material variability and delivers a lot of process data about the conditions under which parts are produced. That’s because the process has grown up with the automotive industry, is well understood by it, and is clearly the dominant method for forming plastics.

Conversely, there is no one process that dominates composites manufacturing. Fabricators can choose from infusion, resin transfer molding (and it’s nearly infinite variations), pultrusion, sprayup, hand layup, automated fiber placement, compression molding and more. Further, composites fabrication still relies heavily on manual labor, which inevitably introduces some inconsistency and variability. Auto OEMs hate variability.

John Bozzelli, a consultant to the injection molding industry and a proponent of scientific molding (molding based on principles of thermo- and fluid-dynamics), notes that the automotive OEMs’ use of PPAP (production part approval process) puts heavy emphasis on manufacturing process control. This means processes must be repeatable and well documented so that the supplier can “respond to a bad part and fix any problems in the process,” he says. In injection molding, he notes, there are certain — and well-known — process parameters that are critical to producing a quality part. Composites fabricators who want to be in the automotive supply chain would have to make a similar determination about their process. However, given the diversity of materials and processes, coming to a consensus on process parameter criticality has been a challenge. “If someone could come out and establish that for composites manufacturing, it would be a big help,” he says.

There are, in fact, few tools in the composites industry that provide the reliable, meaningful, consistent process data necessary to characterize the health of a given manufacturing system. For example, aerospace composites manufacturing is famous for producing high-quality parts, but even in that environment, process control usually means curing a part of a given resin and fiber combination in an autoclave within a certain temperature range over a certain time period at a certain pressure. This temperature/time/pressure combination, of course, provides a well-established window in which the composite should cure, but actual cure may occur outside this window due to changes among any of several variables, including resin viscosity. And the data that might characterize that actual cure are rarely measured, captured or reported.

Measuring, capturing, organizing and updating process and material data is no small task. Unlike steel or any other isotropic material, which retains its physical properties throughout fabrication, composites’ amalgam of fiber, resin, sizing, adhesives, modifiers, fillers and core make it quasi-isotropic. Throw in the variables of fiber placement and orientation and manufacturing process type, and the complexities mount further. Material testing, part testing and good data management will be essential — for all markets served by composites, not just automotive.

It might be that automotive OEMs represent the major market force we need to push composites manufacturing into 21st Century process and data control. If composites professionals do not embrace and meet this challenge, it will be difficult for automakers to take this material and this industry seriously.
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Bio | Dale Brosius

Dale Brosius is the head of his own consulting company and the president of Dayton, Ohio-based Quickstep Composites, the U.S. subsidiary of Australia-based Quickstep Technologies (Bankstown Airport, New South Wales), which develops out-of-autoclave curing processes for advanced composites. His career includes a number of positions at Dow Chemical, Fibereite and Cytec, and for three years he served as the general chair of SPE’s annual Automotive Composites Conference and Exhibition (ACCE). Brosius has a BS in chemical engineering from Texas A&M University and an MBA. Since 2000, he has been a contributing writer for Composites Technology and sister magazine High-Performance Composites.

A n advertisement currently running on U.S. television shows numerous people trying to stop a woman from putting diesel fuel into her luxury passenger car, simply because they believe she is mistakenly grabbing the wrong fueling hose. Turns out, the vehicle she owns is an Audi, with a modern diesel engine, a rarity in America. Our readers in Europe would likely scratch their collective heads about this, given that diesel engines make up a significant portion of the powertrains in European vehicles, and have for decades.

Seeing this advertisement brought back memories of the early 1980s, when Volkswagen (VW, Wolfsburg, Germany) produced hundreds of thousands of diesel-powered Rabbit vehicles — based on the European VW Golf — in VW’s Pennsylvania assembly plant. My general recollection of the Rabbit involves lots of black smoke emanating from the tailpipe. Within a few years, diesel-fueled small cars largely disappeared from the U.S. landscape and standard combustion engines regained overwhelming dominance.

Such was not the case in Europe, where OEMs invested heavily in cleaner, more efficient diesel engines. Today’s diesels offer quiet performance with high fuel economy and greater power. Composites have played a role in these advancements, including the application of glass-reinforced plastics in fuel rails, vacuum pumps and diesel fuel preheaters. A number of thermoplastic and thermoset composites are used under the hood in valve covers, water pumps and other components also common to gasoline engines.

So, are diesel engines poised for large growth in America, or will they achieve only niche status? Time will tell. It seems that we have been through a number of innovations on about 10-year intervals that promise energy independence, higher fuel economy and/or reduced emissions. In each of these developments, composites have provided enabling functionality. Around 1990, there was a strong push to fuel vehicles with compressed natural gas (CNG), offering a lower cost per mile (or km) traveled. At that time, heavy steel pressure vessels were essentially 100 percent of the CNG storage tank market, but new standards were created that incorporated fiberglass or carbon fiber as structural overwraps. These provided additional strength to metal shells or plastic liners, yielding lighter tanks and increased gas capacity. However, the lack of a refueling infrastructure and limited driving range stifled mass adoption. Today, although upwards of 10 million natural gas tanks are produced annually, less than 20 percent have composite overwraps, and only a fraction of these use carbon fiber. CNG makes sense for taxi and delivery fleets, as well as urban buses that return each night to a central location for refueling, but it’s a rarity for families and commuters.

A decade later (circa. 2000), hydrogen fuel cells were all the rage. Japan’s Honda (Tokyo), Germany’s Mercedes-Benz (Stuttgart) and Detroit, Mich.-based General Motors (GM) in the U.S. all set up fuel-cell development centers and put test vehicles on the road. Canadian supplier Ballard Power Systems (Burnaby, British Columbia) was poised to reap large benefits with this technology. Composite bi-polar plates and carbon fiber membranes were developed for fuel cell applications, complemented by high-pressure carbon fiber-reinforced hydrogen storage tanks, but again, lack of infrastructure, high unit costs and cold-weather performance issues stymied adoption on a real production scale.

The past five years have seen rapid growth in hybrid-electric powertrains, ushered in by Toyota’s Prius, and more recently with all-electric (or primarily electric) cars, led by GM’s Volt, Nissan’s (Yokohama, Japan) Leaf, and Tesla’s (Palo Alto, Calif.) Model S. Although composites are used extensively in the battery enclosures for their excellent corrosion resistance and light weight, the body-in-white for each vehicle is largely metallic, so the relatively short driving range per battery charge is a major concern. The introduction of BMW’s (Munich, Germany) i3 electric commuter car changes that paradigm by using a body-in-white composed of carbon fiber and aluminum, and thermoplastic composite body panels, making the vehicle much lighter, albeit at a premium price. Whether this will “energize” the electric vehicle market remains to be seen.

Will enthusiasm for electric-enabled powertrains wane, as it did for natural gas and fuel cells? I think no. Electric vehicles are here to stay, thanks especially to new, much tougher CO₂ emissions and fuel economy regulations. Further, the supply of natural gas, especially in the U.S., has increased (and its cost has decreased) substantially in the past few years, leading to renewed interest in CNG-fueled vehicles, so it’s possible we could see a resurgence, if the refueling issue can be resolved. Although fuel cells face tougher technical issues, their day might yet come as well.

Of course, composites will always present opportunities to lightweight vehicle structures and body panels, regardless of which powertrain is used. It’s just good to know that composites have the potential to make every option more attractive.
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The September Composites Business Index, 49.0, showed that composites business activity contracted at a slower rate for the second consecutive month. But September still marked a fourth consecutive month of contraction.

Four of the six subindices made positive contributions to the overall index in September. The largest jump came in backlogs, which moved to 43.5 from 39.7. However, backlogs have contracted since May 2012. Production also jumped significantly, moving to growth from contraction. Production has grown seven of the first nine months this year. New orders reached their highest level since May. Also positive was supplier deliveries, which lengthened just slightly. Employment grew for the seventh consecutive month but at a slightly slower rate. This had a slightly negative impact on the overall index. The worst performer was exports, which dropped to 46.0 from 48.3, contracting for the 17th consecutive month.

Material prices increased at a faster rate in September, but the rate of increase was the second slowest since November 2012. Prices received jumped to 52.1 from 50.3, the second month this subindex grew at a faster rate. Business expectations fell slightly but were still above the levels reached in the second half of 2012.

After contracting in August for the first time since November 2012, fabricators with more than 250 employees grew in September. Facilities with 100 to 249 employees continued strong, growing at their fastest rate since July 2012. Fabricators with fewer than 100 employees contracted in September and those with 50 to 99 employees did so for the second time in 2013. Fabricators with 20 to 49 employees saw their best business conditions since March.

Two regions expanded in September. Both the West South Central and the Middle Atlantic grew for the second month in a row. New England and the South Atlantic moved from growth to contraction. The East North Central, Pacific, and West North Central regions contracted at a slower rate.

Capital spending plans were at their lowest level since March 2013. However, planned expenditures were 11 percent higher than they were in September 2012.

The CBI of 51.2 in October, however, showed business activity had expanded for the first time since April 2013. The rate of growth was the fastest since March 2013. October’s index was 6.2 percent higher than it was in October 2012. This is the second straight month the index has improved compared to the same month one year ago.

New orders jumped dramatically, growing for the first time since April 2013 and reaching their fastest rate of growth since May 2012. Production grew faster for the second month in a row, reaching its highest growth rate since May 2012. Backlogs still contracted at a significant rate, but slower than in the previous two months. Employment had grown at a fairly constant rate the previous four months. Exports continued to contract as the dollar remained relatively strong. Supplier deliveries lengthened again. Material prices increased at a faster rate for the second month straight. Prices received increased modestly for the third straight month. Business expectations jumped, reaching its highest level since April 2012.

Midsize fabricators (50 to 249 employees) grew fast in October. Facilities with 100 to 249 employees grew for the ninth time in 12 months. Fabricators with more than 250 employees contracted modestly for the second time in three months. Facilities with fewer than 19 employees were virtually unchanged after the rate of contraction slowed dramatically.

The Mountain region grew at an incredibly fast rate. Its index was 59.2 — the highest since March 2012. The New England, Pacific, and East North Central regions moved to expansion from contraction. The Middle Atlantic region was flat after two months of growth. The South Atlantic and West North Central contracted faster in October.

Future capital spending plans were up 1.5 percent compared to October 2012. October was the second month of growth in capital spending plans.
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Automotive innovation is the watchword as composite body panel laminates that double as batteries, and a glass/polycarbonate sandwich trunk lid, headline the industry’s news.

Volvo debuts composite BATTERY-IN-BODY-PANEL technology

Volvo Car Group (Gothenburg, Sweden) has implemented a revolutionary concept for lightweight, structural energy-storage components that would permit automakers to integrally mold battery components within composite auto body-panel laminates. The technology, designed to improve the utility and efficiency of future electric vehicles (EVs), was developed during a research project funded and overseen by the European Union. Imperial College London took the academic lead and worked with eight other major participants, including Nanocyl (Sambreville, Belgium) and Cytec Industrial Materials (Heanor, Derbyshire, U.K.), with Volvo as the sole participating auto OEM. (CompositesWorld first covered the project in February 2010: “Composites partnership researches body/battery combo for electric cars,” http://short.compositesworld.com/t3ZObYv6.)

The project team identified a feasible solution to the weight, size and cost disadvantages associated with the heavy, bulky batteries used in hybrid-electric and plug-in electric cars today: a material consisting of carbon fiber combined with carbon nanotubes.

The focus of the project was on the combination of carbon fiber laminates that contain carbon nanotubes combined with a polymer resin. The result, says Volvo, is a very advanced nanomaterial — in effect, structural supercapacitors. The laminate is layed up, shaped and then cured in an oven; the nanotubes are integrated within the component skin. This material can be molded to replace existing components on the vehicle, such as body panels, and then be used to charge and store electrical energy (see diagram). According to Volvo, the material is recharged and energized by the use of brake energy regeneration in the car or by plugging into the electrical grid. Like a conventional battery, it supplies power to the EV’s electric motor. That said, experimental work has shown that this material not only charges and stores energy faster than conventional batteries, but it is also suitable for structural applications. The research project took place over nearly four years and has now been realized in the form of body panels on a Volvo S80 experimental car.

Volvo has evaluated the technology by creating two components for testing and development: a boot (trunk) lid and a plenum cover that were tested on the S80. The boot lid is a functioning storage component that has the potential to replace the standard batteries in today’s cars, yet it’s lighter than a standard boot lid, saving weight. The new plenum has demonstrated that it can also replace both the rally bar, a strong structural piece that stabilizes the car in the front, and the start-stop battery. This saves more than 50 percent in weight, compared to previous materials, and is powerful enough to supply energy to the car’s 12-volt electrical system.

Volvo says that “complete” substitution of an electric car’s components with the new material could cut the overall weight by more than 15 percent, which would save money and result in lower environmental impacts. The carmaker adds that EVs play an important role in its future product portfolio, and it will continue the work.
Bayer MaterialScience (Leverkusen, Germany) reported on Oct. 10 that it has developed a new sandwich structure for use in the manufacture of automotive body panels. At the K 2013 plastics trade fair (Oct. 16-23, Düsseldorf, Germany), Bayer MaterialScience showcased a sample trunk lid that features this technology.

“To make the outer layer, continuous glass fiber mats are impregnated with a thermoplastic polymer formulated from polycarbonate,” explains Ulrich Grosser, Bayer’s team leader for advanced technologies (photo at right). “All the fibers are wetted and fully coated by the plastic matrix. This is the key to the high stiffness of the skins in a sandwich structure. Polycarbonate (PC) blends, such as Bayer’s Makroblend, are said to shrink minimally, and the process reportedly results in a smooth, high-quality, paintable surface. Finish coatings based on polyurethane (PU) raw materials are available from Bayer.

In a second step, the top and bottom of the trunk lid are joined, and the resulting hollow space is filled with the company’s Baysafe-brand PU foam. The foam’s low density minimizes weight and reduces fuel consumption and CO₂ emissions or, in an electric car, it saves battery power and increases the vehicle’s range.

The foam’s stiffness and good adhesion to the outer skin of the part is said to enhance the part’s resistance to minor damage. In the event of a collision, the foam reportedly absorbs energy, contributing to the safety of passengers and pedestrians and enhances thermal insulation, improving energy management inside a vehicle.

Further, antennae can be embedded in the foam, efficiently and permanently. Unlike metal components, polymers permit undisturbed reception across a wide frequency range. Additional functions (e.g., electrical fixtures for lighting) could be integrated into the sandwich component, says Bayer.

To promote the realistic use of the concept part in a vehicle, Bayer also developed an intelligent solution for mounting it to the rear of the vehicle. “The task was to devise a robust and lasting connection between the hinge and the lightweight structure of the trunk lid. To find a solution, we studied how trees are anchored to the forest floor,” Grosser explains. Bayer researchers optimized the shape of the hinge mount using computer-aided engineering (CAE). The resulting plastic structure looks remarkably like the roots of a tree in the ground. Tests confirm that the hinge mount can be attached easily and holds very firmly in the lightweight foam core.

CORRECTION

An alert reader recently spotted a factual error in “Making continuous composite pipes,” an online sidebar (visit http://short.compositesworld.com/O5lwNelt) to the Engineering Insights feature titled “Designing for high pressure: Large-diameter underground pipe,” featured in the June 2012 issue of CT. Author Sara Black began the story thus:

“The continuous filament winding process was developed in the 1970s by Danish inventor Frede Hilmar Drosthholm, and it was commercialized first by Toledo, Ohio-based Owens Corning’s engineered pipe systems business, in partnership with several entities, including Amiantit (Dammam, Saudi Arabia) and Vera Fabrikker (later Flowtite Pipe and Tank AS, Sandefjord, Norway).”

As it turns out, Frede Hilmar Drosthholm was the inventor of the advancing mandrel machine but not the continuous filament winding process for fiberglass pipes and tanks. It was invented by Agnar Gilbu of Sandefjord, Norway, who used the machine devised by Drosthholm in his process.

He took his production method to Vera Fabrikker (at that time a subsidiary of Sandefjord-based global paint supplier Jotun) as a possible use for their resin. Production started in 1965, but, initially, the process was used only to make tanks. In 1968, Vera Fabrikker supplied the first pipes to customers. Veroc Technology AS was established in 1977 as a joint venture between Vera Fabrikker and Owens Corning (Toledo, Ohio). The U.S. patents were granted at this time, which gave rise to the mistaken impression that Drosthholm was the inventor of the process.

According to our source, Amiantit was not a partner, but rather a customer, of Veroc for many years. When Owens Corning went through bankruptcy in 2001 due to asbestos-related litigation, Amiantit reportedly acquired the former Veroc, which had by then acquired a new name: Flowtite Pipe and Tank AS.

For more historical details, visit http://www.flowtite.com/About-History.aspx.
Composites manufacturer Continental Structural Plastics (CSP, Auburn Hills, Mich.) announced on Oct. 23 that it has moved into its new 70,000-ft² (6,500m²) world headquarters facility. Located at 255 Rex Blvd. in Auburn Hills, the new location expands and enhances CSP’s composite material research, formulation and design capabilities with an R&D center; executive, sales and administrative offices; an employee fitness center; several state-of-the-art conference rooms; and a 3,300-ft² (305m²) showroom and visitor center.

“The goal is to better serve our customers domestically and around the world,” said Frank Macher, chairman and CEO of CSP. “The new facility allows us to accommodate growing customer needs in durable, lightweight solutions, diversified-composite formulation and sustainability.”

CSP’s 29,000-ft² (2,690m²) R&D and Prototype Center is staffed by a team of chemists, chemical engineers, polymer engineers, materials scientists and technicians, who collectively hold four Ph.D.s, four MS degrees and five BS degrees. The facility’s expanded features include a prototype sheet molding compound (SMC) line that has been refurbished and upgraded to handle carbon fiber. Also in-house are a 50-ton, 100-ton, and a new 200-ton press suitable for molding test plaques and parts. Provisions have been made to expand into resin transfer molding (RTM) and thermoplastic composite development and to acquire additional equipment, including a larger press for molding prototype automotive parts and a second compounding line for fabricating carbon fiber SMC and prepreg.

CSP’s new Polymer Development and Analysis Lab includes thermal analysis testing (DSC, DMA, TMA, and TGA), optical and scanning electron microscopy (SEM), chemical property testing (FTIR/infrared spectroscopy, and EDS/energy-dispersive X-ray spectroscopy) and a fully equipped mechanical and physical property test area. In addition, the center contains a wet lab that is suitable for polymer synthesis and chemical testing. The Engineering and Prototype area is equipped with paint booths, conditioning ovens, environmental and salt-spray chambers, coordinate measurement machine (CMM) tables and a machining area for building test fixtures.

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Although the mood was positive and activity on the show floor was energetic, IBEX attendance was unexpectedly flat — officially “equal to last year” at 4,700. They expressed excitement that in 2014 the show will cast off from its inland site in Louisville to new moorings in Tampa, Fla. Located on the waterfront, close to hotels and attractions, the Tampa Convention Center is a world-class event space. One exhibitor said of the return to Florida that “99 percent of our customers are within a few hours drive.” Another noted, “I think we’ll see more attendees from each shop if they can drive and don’t have to lose so many work days.”

The question now is how the industry will respond. Rick Pitino, head basketball coach for the University of Louisville and IBEX 2013 keynote speaker, challenged, “If you face adversity, what will get you through, every time, is your dedication and your passion.” Dammrich, in his presentation, went one step further: “We are an ecosystem — we’re all interconnected. We need the engagement of the entire industry.” He urged increased outreach to youth and minorities and an increase in hands-on training as well as continued fostering of innovation to make sure boating is strong enough to maintain and grow the 964,000 jobs and $121 billion of value it contributes to the U.S. economy.

On the subject of innovation, IBEX did not disappoint. Composites-oriented seminar titles emphasized progressive improvement: “Adapting Open Molds for Infusion”; “Prepreg Best Practices”; and “What Do You Mean: Green?,” which introduced environmentally sound options during design, build, operation and disposal. Of note: in Stanford University lifecycle assessments — ranging from melting sand for fiberglass through product disposal — composites bested other materials in every category of pollution. Other presentations offered practical advice: How to bond to infused laminates; increasing productivity and cutting costs through temperature control; and core materials selection strategies that minimize purchasing issues while maximizing lightweighting.

SUPPLIERS JOIN FORCES
There was evidence at this year’s IBEX of what could prove to be a major trend toward mergers and acquisitions (M&A) as suppliers seek to provide wider product offerings and more customized product...
development. A prime example was the first IBEX exhibitor presence of ATC Scott Bader. Wollaston, U.K.-based Scott Bader acquired Canada-based ATC (Burlington, Ontario) in February 2013. The combined company now offers a full spectrum of solutions, from polyester bonding pastes to methyl methacrylate (MMA) structural adhesives, for composites in marine and other industries. At its booth, ATC Scott Bader offered a wide range of Crestopol UA adhesives, and suggested stringers as an excellent application. For bonded nonstructural bulkheads, polyester adhesives were on offer. And for bonding composites to metals and plastics, the company offered MMAs and noted that ATC Scott Bader has the ability to develop hybrids all along the adhesives spectrum.

Polyumac Inc. (Miami, Fla.) also broadened its product line through its acquisition by Changzhou Tiansheng New Materials Co. Ltd. (Changzhou, China) in December 2012. Polyumac’s polyurethane, polyester and polyimide foams are reportedly complementary to Tiansheng’s own series of Strucell products, which include polyvinyl chloride (PVC), cyclic imide and thermoplastic structural foams, as well as Rigicore P, which is made almost completely from PVC foam scraps and recycled core. Tiansheng also offers Strucell plastic honeycomb since its acquisition of Qindao Tubus Honeycomb Ltd. (Qingdao, China). Tiansheng also sees itself as moving from material supplier to design-integrated manufacturer, offering strong R&D and a range of solutions for composites. According to national sales manager Rod Bearden, Polyumac will complete its U.S. corporate relaunch by year’s end, including a new Web site.

Illinois Tool Works (ITW) merged its Plexus, Spraycore and Devcon operations into ITW Polymers Adhesives (Danvers, Mass.) with the aim to create larger divisions focused on innovative products and improved customer service. National sales manager Tom Glast noted, “This new core group will draw from that corporate strength, targeting a larger product offering and tailored solutions for not just marine, but all transportation and industrial end-uses.”

**EDUCATION AND CONSULTATION**

A continuing trend toward collaboration between suppliers and manufacturers was exemplified by Composite Consulting Group (CCG, an offshoot of DIAB Inc., DeSoto, Texas). CCG presented three seminars: “The Double-Bag Debate Update,” “Inside the Bag: Vacuum-Pressure Analysis” and “Infusing Stringers and Floors.” The latter was copresented by André Cocquyt and dealt with infusing a hull and stringers simultaneously vs. infusing stringer systems after the hull. “We don’t see a size limit for co-infusing stringers with the hull,” remarked CCG Americas manager James Jones. He says, “The challenging part is vacuum bagging all of the geometry.” CCG’s senior process specialist Belle Blanding worked with Midnight Express Boats (Hollywood, Fla.) to infuse a 39-ft/11.9 m hull with the main longitudinal stiffeners and aft bulkhead. She notes, “It took two extra days to complete the setup but eliminated a second infusion plus all of the surface preparation and adhesive application that would have been required for secondary bonding of the stringers.” Midnight Express’ production manager, Tague Estes, added, “Co-infusing the stringers ends up cutting close to two days out of the overall build, plus it contributes to the removal of almost 4,000 lb (1,814 kg) from the part vs. open molding.

Meanwhile, Composites One (Arlington Heights, Ill.) moved its Closed Molding University inside this year and, for the first time at IBEX, included carbon fiber/epoxy prepreg in its demonstrations. “The marine industry is starting to use more advanced materials for lightweight and higher performance,” says marketing manager Marcy Offner. Composites One carries prepreg products from Seoul, Korea-based producer Hankuk Fiber Co. Ltd. Vacuum infusion demonstrations also featured Micromesh carbon fiber fabric from Vectorply (Phenix City, Ala.).

**NEW, IMPROVED, EXPANDED**

First-time IBEX exhibitor CoreLite (Miami, Fla.) previously served product to other suppliers. Now it markets its own balsa, which is grown, harvested and milled in Ecuador. The balsa is processed into finished core materials at the company’s Miami facility. CoreLite introduced two core materials: Balsasud balsa is available from 8 to 12 lb/ft³ in a wide range of thicknesses, either rigid or controllable, with scrim and either coated or uncoated.

HK Research (Hickory, N.C.) introduced its new High Definition EXTREME “METAL FLEX” in-mold coating, which provides boatbuilders with a durable automotive-type “metal-flake” finish that can be applied with conventional gel-coating equipment.
Don’t miss the opportunity to learn from the industry’s leading innovators and network with decision makers and key executives from all aspects of the carbon fiber supply chain!

This year we’re including an optional tour of Oak Ridge National Laboratory’s carbon fiber manufacturing facilities!

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Emerging Opportunities and Challenges for Carbon Fiber in Passenger Automobiles – Is the CFRP Industry Ready for Mass Production?

Presented by
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Don’t miss this opportunity to learn from the industry’s leading innovators and network with decision makers and key executives from all aspects of the carbon fiber supply chain!

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Marine Concepts/JRI Ventures Inc. (Cape Coral, Fla.) has expanded its operations into the old Wellcraft plant in Sarasota, Fla., which it purchased in November 2012. The company’s operations make use of only 140,000 ft²/13,006m² of the facility, which houses its #5 and #6 CNC machines, so the company says it has plenty of space left for growth. Customer-focused investment in the latest technology and industry talent — and a strong rebound in the marine market — reportedly enabled Marine Concepts to hire its 200th employee in late 2013, a significant recovery from a recession low of 30 employees in 2009.

MultiPanel (Dania, Fla.) showed its rigid but easily formed polyurethane foam panel, intended as an alternative to plywood or medium-density fiberboard MDF in marine interiors and in the construction and transportation sectors. As a core and backing for veneers and cosmetic surfaces, it is waterproof and is less than one-third the weight of plywood at 25-mm/0.98-inch thick, and one-quarter the weight of 18-mm/0.71-inch thick MDF. MultiPanel-brand foam is available in 4-ft by 8-ft (1.2m by 2.4m) sheets and can be kitted.

PRO-SET (Bay City, Mich.) showcased its new 251HT hardener and 151HT epoxy resin systems for higher-temperature tooling and part fabrication. According to product manager Joe Parker, “If you need a 250°F [121°C] Tg, the 251HT hardener can be used with all standard PRO-SET resins, which allows fabrication with any process: infusion, light resin transfer molding, wet bagging or contact molding. It can also produce a 350°F [177°C] Tg with a 300°F [149°C] cure when used with the 151HT resin.” The system reportedly allows 8 to 10 hours of working time at room temperature, thoroughly wets out carbon fabrics and exhibits good cosmetics.

Zoltek Corp. (St. Louis, Mo.) showed its commercial-grade (50K) carbon fiber products for marine applications and discussed with attendees carbon fiber solutions for significant weight savings vs. fiberglass. Notably, the company pointed out that Panex 35 unidirectional and multidirectional fabrics feature sizings that are optimized to infuse well with vinyl ester resins commonly used in marine applications. Panex 35 prepreg tapes were said to offer efficient composite fabrication, often used as skins with foam or honeycomb cores to further reduce weight. Additionally, Zoltek provides carbon fiber application assistance to its customers.
In 2013, the SPE’s annual Automotive Composites Conference & Exhibition gets a bigger venue and an expanded technical program — and boasts its best attendance ever.

At its new venue, the Suburban Collection Showplace and the adjoining Hyatt Place Hotel in Novi, Mich., the Society of Plastics Engineers’ (SPE) Automotive Composites Conference & Exhibition (ACCE) hosted nearly 900 attendees and featured a strong four-track program of papers and a crowded exhibit hall.

As always, presenters provided a wealth of information on innovations in materials and part design, as well as much improved and particularly important at this juncture — faster molding processes, citing notable examples of successful composite applications in production autos. Many of the innovations have sprung from Europe, where automakers are scrambling to reduce vehicle weight and avoid strict financial penalties for failing to meet vehicle emission targets. And, despite one presenter’s statement that “the BMW i3/i8 program is equivalent to the Boeing 787 Dreamliner program for automotive composites,” some OEM representatives expressed doubts about full-scale adoption of composite materials.

That said, SPE ACCE cochair Antony Dodworth (Dodworth Design, Buckingham, U.K.) presented the award for Best Paper to one of several companies that might offer a significant piece of the composites-adoption puzzle; e-Xstream Engineering (Louvain-la-Neuve, Belgium) took top honors for its discussion of virtual prototyping. The company’s CEO, Roger Assaker, spoke on “Multi-Scale Modeling of Failure of Continuous Carbon Fiber Composites Applications to Coupon Tests,” noting that e-Xstream is experimentally validating its DIGIMAT software for virtual testing of continuous fiber-reinforced composites and refining the calculations to more closely match test data. He pointed out that if composites are to successfully move into the body-in-white and other structural parts, software that already permits reliable progressive failure analysis of short-fiber-reinforced parts must be adapted and refined to accurately predict the behavior of continuous-fiber components.

That sentiment was echoed by R. Byron Pipes, the John L. Bray Distinguished Professor of Engineering at Purdue University (Lafayette, Ind.), who presented a new vision for moving engineers from a metals-centric and empirically based focus on isotropic material properties to a radical new paradigm in which engineers are aggressively introduced to the nonisotropic nature of composites. His vision includes the imperative that virtual simulation sup-
“strong” demand for carbon fiber in autos will accelerate after 2015. Jan Anders-Månson (École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland) explored some of the reasons why composites have not yet been widely adopted in automotive applications. He believes that recycling is a huge issue that needs more attention, and he advocated replacing virgin carbon fibers with recycled carbon fibers as a means to close the materials cost gap with steel.

A standout paper was presented by Marcie Kurcz, North America business manager for resin maker Polyscope (Geleen, The Netherlands). She described the design and manufacture of the semiconvertible sunroof frame for the Citroën DS3 Cabrio model, designed by Webasto (Munich, Germany) and molded by Shaper (La Séguinière, France) using a modified glass fiber-reinforced styrene maleic anhydride (SMA) resin from Polyscope. The composite part offers significant cost savings over other materials, enables part integration (seven parts were combined into one) and secured a 40 percent weight reduction compared to trial parts made from other considered materials. The glass/SMA part, she said, offers a viable “value proposition” that clearly favors the selection of composites.

In another session, there was considerable audience interest in a newly introduced process offered by Dale Brosius, president of Quickstep Composites LLC (Dayton, Ohio), the U.S. subsidiary of Australia-based Quickstep Technologies (Bankstown Airport, New South Wales). Called Resin Spray Transfer (RST), this fast-cycle method takes an unusual approach. The structural resin is robotically sprayed directly onto the mold surface, and a fiber preform is placed over it. The resin, then, needs to flow only in the z-direction to wet out the reinforcement, which reportedly makes it possible to consistently produce a Class A finish. The impregnated preform is then cured in a Quickstep hot fluid machine. According to Brosius, a cycle time of 10 minutes is possible.

Several papers and keynotes discussed new and ongoing industry collaborations aimed at increasing the use of composites on high-production vehicles. Greg Rucks of the Rocky Mountain Institute (RMI, Snowmass, Colo.), an automotive think tank that Rucks called a “think and do tank,” believes that the successful introduction of a few specific parts on four mainstream vehicle models...
could double the global carbon fiber demand. His group’s “launch pad” aims to identify such parts, which might include a rear hatch inner, a door inner, an engine cradle and/or a seat structure made with large-tow carbon fiber and no cosmetic finish. Rucks notes that the effort offers a very viable value proposition: “Even though steel is less expensive, the three-year fuel savings for vehicle fleets made with the lighter carbon parts would offset the entire carbon fiber cost premium.” The RMI is putting together a supply chain team to create an innovation hub that will enable production of selected parts by 2018. RMI also noted that it is looking for an automotive OEM partner.

This year, for the first time, the industry discussion panel included two representatives from the aluminum industry: Doug Richman of Kaiser Aluminum (Bingham Farms, Mich.) and Mario Greco of Alcoa (Pittsburgh, Pa.). A point repeatedly raised by the panel members was that widespread use of structural composites in the auto industry is possible, and attractive, but adoption repeatedly stalls when the industry tries to make a business case because composite material costs are still high and processing speeds and part quality are still evolving. Several panel members said problems that center around attachments and fastening simply aren’t solved yet. Panelists also noted that the lack of predictive analysis software, training and education still hampers the industry’s familiarity with composites. Most panelists agreed that lifecycle analysis (LCA) is becoming more important to both OEMs and consumers, and that LCA analyses show that carbon fiber does not yet fare as well as aluminum, which enjoys a global recycling push. But panelist and keynoter Jai Venkatesan of Dow Chemical Co. (Midland, Mich.) pointed out that over time, the value of composites per unit cost has grown, because they vastly improve fuel efficiency and enable parts integration. He asserted that in reality, molding process speed has accelerated significantly in the past two decades so processing isn’t the roadblock anymore. The problem remains raw material cost. But Venkatesan believes lessons can be transferred from aerospace to automotive in order to drive “disruptive innovation.”

Read this article online | http://short.compositesworld.com/KjISAXDg.
Progress is underway for the Materials Genome Initiative (MGI). This public/private endeavor, launched by the Obama Administration in mid-2011, committed the federal government to work with industry and academic partners to double the pace of advanced materials development. Program goals include vehicles that are safer and more fuel efficient; packaging that keeps food fresher and preserves nutrition; armored vests that better protect soldiers; and metals that can tolerate extreme temperatures and radiation in spacecraft and satellites.

Overseen by the White House Office of Science and Technology Policy (OSTP), the MGI aims to coordinate federal materials science research across multiple agencies and encourage private-sector and academic researchers to develop and share basic materials science discovery data to speed innovation, much like geneticists accelerated the Human Genome Project by openly sharing basic DNA sequence data. CT asked Cyrus Wadia, OSTP’s assistant director for clean energy and materials R&D, to weigh in on the endeavor’s current and future relationship with the composites industry.

**CT:** How does the MGI program interact with the composites manufacturing industry?

**CW:** MGI is a multi-agency effort that supports all industrial sectors involved with advanced materials systems, ranging from electronic materials to lightweight composites. As a materials class, the composites manufacturing industry has already played an instrumental role in shaping the MGI. For example, early in the genesis of the MGI, the OSTP had direct engagements with over 12 materials professional societies including, SAMPE [The Society for the Advancement of Material and Process Engineering (Covina, Calif.)], TMS [The Minerals, Metals & Materials Society (Warrendale, Pa.)], MRS [The Minerals Research Society (also in Warrendale)] and ACerS [The American Ceramic Society (Westerville, Ohio)], all of which represent members in the composites field. Furthermore, in the first two fiscal years of the MGI, the federal government has made more than 70 R&D grants across the Departments of Defense and Energy, the National Science Foundation (NSF) the National Institute of Standards and Technology (NIST) and the National...
Aeronautics and Space Admin. (NASA), including a number that involve the ceramics sector. A good example is the five-year, $10 million effort launched last year by the Air Force Research Laboratory’s Materials and Manufacturing Directorate on advanced polymer matrix composites (PMCs) for aerospace systems.

**CT:** What impact is the MGI expected to have specifically on the composites manufacturing industry?

**CW:** To appreciate the significant impact that the MGI can have, consider that the full potential of applying advanced PMCs to aerospace systems is limited today by the lack of integrated simulation tools that capture enough detail to adequately represent the complexity of these high-performance materials in systems design. As noted above, the Air Force Research Lab is leading an industry/academia/government laboratory collaboration that involves General Electric, Lockheed Martin, Autodesk, Convergent Materials, the University of Dayton Research Institute and the University of Michigan to provide the aerospace industry with the integrated engineering tools needed to account for this material’s (PMC) complexity across different spatial and temporal domains.

For example, industry currently lacks an ability to link the chemistry of PMC processing with mechanical performance, particularly the load response and damage evolution for high-temperature PMCs. Therefore, the current design process relies on incrementally building confidence in composite performance for a specific application by repetitive analysis and testing, resulting in component designs that are overly conservative or inadequate for areas where the structure is complex. These tools will be used for design of an airframe wingbox and an engine bypass duct to demonstrate reduced cost, time and risk for the insertion of these materials into use. In addition, reduced conservatism in designs and accelerated transition of next-generation materials will enable performance improvements, resulting in significant fuel savings for both military and commercial aircraft.

**CT:** What is likely to happen to MGI at the end of President Obama’s Administration?

**CW:** MGI is not just a federal initiative — it is a growing movement both inside and outside of the federal government. From the government perspective, the MGI now includes active engagement by five federal agencies which are participating in two ways: individually through their mission-related activities (including funding

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**NEW COMMITMENTS TO MGI**

Committments to the Materials Genome Initiative (MGI) announced this year build on support from five participating MGI agencies — the U.S. Department of Defense and Energy, the National Science Foundation (NSF), the National Institute of Standards and Technology (NIST) and the National Aeronautics and Space Admin. (NASA) — which, in 2012, made more than 70 awards to support MGI-related research, totaling nearly $63 million. The academic and private sectors have responded in kind. More than 60 universities and companies committed to advance the MGI through education and research, including the release of material properties databases and partnerships among universities, industry and national labs. Other news:

- NIST is committing $25 million over five years to form a second center of excellence that will create a collaborative environment and concentration of technical capability to accelerate materials discovery and development.
- NIST also will collaborate with ASM International (Materials Park, Ohio) and its Computational Materials Data Network to establish an open, digital repository of materials data.
- In support of MGI, the University of Wisconsin, Madison, and the Georgia Institute of Technology are creating new “institutes in materials innovation” with collective investments totaling about $15 million, and the University of Michigan has committed to invest an additional $20 million to MGI programs that are already underway. Moreover, all three universities will partner to launch a nationwide dialogue and build a nationwide “materials innovation accelerator network.”
- Lawrence Berkeley National Laboratory (LBNL), Massachusetts Institute of Technology (MIT) and Intermolecular Inc. (San Jose, Calif.) are working together to more accurately predict material behavior with software
programs such as the NSF’s “Designing Materials to Revolutionize and Engineer Our Future”) and focused investments such as the NIST’s upcoming Center of Excellence in Advanced Materials, and also in a coordinated fashion through the Subcommittee on the Materials Genome Initiative of the National Science and Technology Council — a cabinet-level interagency coordinating body overseen by the White House. At the same time, the private sector — both industry and academia — has made great strides in adopting and internalizing MGI’s goals and approaches to innovations, with a growing number of university departments and research institutions committing to advance the principles behind this initiative.

At the two-year anniversary of MGI this past June, OSTP announced a number of new private sector commitments and the addition of seven more academic institutions embarking on new educational efforts around MGI goals that include curricula development, new graduate degrees and research opportunities. These recent announcements [see “New commitments to MGI,” p. 20], in addition to those made more than a year ago, demonstrate the long-term commitment the materials research community has made toward achieving the goals of MGI — a commitment we expect will continue well beyond the current administration. | CT |

Senior Editor
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Tools made openly available by LBNL. Building on data from existing high-throughput combinatorial experimentation and simulation, researchers anticipate a set of tools that could increase the speed of new materials development tenfold or more over conventional approaches.

- Harvard University and IBM (Armonk, N.Y.) are releasing a free, open database describing 2.3 million new materials for potential use in solar cells — the largest of its kind.
- Building on pledges toward MGI made by more than 60 companies and universities, seven more academic institutions and a software company are announcing new educational efforts around MGI that include curricula development, new graduate degrees and research opportunities.

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Reusable vacuum membranes

As the composites industry matures, manufacturers continue their search for technology that will maximize production and minimize cost. A growing number of resin infusion shops — including some aerospace manufacturers — are finding this combination in reusable vacuum bag (RVB) technology. Proponents say these stretchy membranes can replace disposable bagging films and even rigid countermolds, and they offer molders a wealth of advantages, including improved part-to-part quality and greater shop safety and cleanliness. No less important, they provide a way to cut down on consumables and reduce a shop's waste stream. RVBs do, however, require capital expenditure and offer challenges that must be overcome for proper implementation, and they aren't always the right way to go in every part process situation.

"As with any process tool, there’s a list of factors to consider," says Rich Rydin of RVB system provider SR Composites LLC (Henderson, Nev.). "Each RVB system has pros and cons, and fabricators should consider the relative ease of building and using the RVB, its tolerance for a specific resin chemistry and processing temperature, and, of course, the aggregate cost per square foot."

That said, Alan Harper, director of Alan Harper Composites Ltd. (Saltash, Cornwall, U.K.), insists, "This is game-changing technology. RVBs are a very sensible economic solution for anyone making more than eight similar parts, whether it be by infusion, prepreg molding or Light RTM" (see last entry in "Learn More," p. 29).
a colloidal state, allowing further processing into sheet form or geometric shapes. To make a reusable vacuum bag, the water that surrounds the elastomer particles in the liquid film must be evaporated.

Silicone sheet goods, especially high-strength compounds that are postcured for higher heat resistance, have been used for decades as membranes, diaphragms and envelope bags in production tooling that is autoclave-processed, and with secondary-operation tools (bonding fixtures, for example), says Greg Lindstrom, president of Torr Technologies Inc. (Auburn, Wash.), a supplier of membranes and RVBs for aerospace customers. Major suppliers of silicone sheet goods and liquid formulations include Wacker Silicones (Munich, Germany), Arlon Silicone Technologies (Bear, Del.), Dow Corning Silicones (Midland, Mich.), Shin Etsu (Tokyo, Japan), Mosites Rubber Co. (Pt. Worth, Texas) and ACC Silicones Ltd. (Amber House, Bridgwater, Somerset, U.K.).

Silicones moved down market from high-end autoclave applications to low-cost infusion, says Harper, when suppliers began to offer room-temperature vulcanizing (RTV), lower-viscosity, two-part, platinum-cured silicone formulations. These more user-friendly forms were stable with good properties and could be sprayed, poured, brushed or troweled into place to create a custom silicone bag for infusion, adds Brad Frikkers, global sales and marketing manager at Smooth-On (Easton, Pa.), a supplier of material formulations for molding, modeling and casting.

Various means are available to make a custom RVB for low-temperature, nonautoclave cures, including seaming silicone sheet stock, but the fastest and most common method is to use a dedicated spray machine that employs either an atomizing spray head or a splatter-type head to create a film directly on the mold or, in some cases, a dummy part in the mold, depending on the required fit. Multiple layers are built up to the desired RVB thickness, typically from 0.04 inch/1 mm to 0.375 inch/9.5 mm. The working pot times, air assist velocity needed for spraying, spray equipment cleanup requirements and specifics like final bag thickness vs. weight and cure time vary by material type and supplier (For details about what individual suppliers recommend, see “Learn More.”) A wide range of edge seals are available; many are proprietary or based on patent-pending technology. The simplest seal for a frameless RVB is a half-round or V-shaped profile affixed to the lower tool’s flat flange, which is then covered with the elastomer spray. After cure, the profile is pulled out, leaving a channel a few inches from the RVB edge.

Vacuum and resin ports are created by bonding port components to the bag or placing them at desired locations, masking them against the spray and then spraying the material over them. Resin flow channels also can be designed into the bag. When a vacuum is pulled through the ports and the perimeter channel, the RVB is pulled down against the tool. Other edge seal options include types of key locks, where a female channel (connected to the vacuum source) is bonded to the tool flange and a male key component is bonded to the bag; when they are pressed together, they form a secure vacuum lock. Autoclave RVBs typically use metal edge frames with integral vacuum seals (see “RVB Insider Insights,” p. 25).

**Similarieties and Differences**

Both silicone and natural rubber offer benefits for certain applications (see the summary in Table 1, above). They also have process and handling similarities, together with some uniquely individual characteristics. An important similarity is that epoxy resins, in particular, will attack all types of RVBs, breaking them down at a faster rate than polyester or vinyl ester resins. Ashley

**Table 1: Silicone and natural rubber each have unique advantages.**

<table>
<thead>
<tr>
<th>Property</th>
<th>Silicone rubber</th>
<th>Natural rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical resistance</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Temperature resistance</td>
<td>Excellent</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tear resistance/elongation</td>
<td>Dependent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Mold release needed</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Cloth reinforcement needed</td>
<td>Dependent</td>
<td>No</td>
</tr>
<tr>
<td>Repairable</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

An operator sprays an additional film layer of liquid, two-component, platinum-catalyzed silicone onto a prepped mold. Note the resin flow channel and vacuum port located along the mold axis. Dedicated spray equipment is recommended for spraying either silicone or natural rubber, shown in inset photo. Ashley
In terms of heat resistance, natural and silicone rubbers differ. Lindstrom rates Torr’s silicone systems at 400°F/205°C for continuous use in autoclave conditions. And Harper says there are autoclave-rated silicone RVBs that can handle temperatures as high as 464°F/240°C. Natural rubber normally can’t tolerate such high heat, but SR Composites says its Sprayomer natural rubber RVB is modified to handle service temperatures that range from 250°F to 390°F (121°F to 199°C).

SR Composites’ Rydin recommends that all RVBs (both natural and synthetic) be cured fully before use to maximize their useful life. “A simple confirmation of best cure practice for a given elastomer is to ask your elastomer supplier how long their ASTM tensile and tear specimens were cured prior to testing,” says Rydin. Duncan, the RVB expert at distributor Composites One (Arlington Heights, Ill.), explains that the styrene in polyester resin can penetrate the silicone, because of its permeability, and eventually break it down. Frikkers contends that platinum-catalyzed, addition-cure silicones are more chemically stable and are, therefore, less vulnerable to breakdown than less costly tin-catalyzed silicones (which cure via a condensation reaction). Although shops like to store bags in plastic to keep them clean, Duncan says RVBs should be allowed to breathe between uses to allow any trapped compounds to exit.

“How the silicone chemistry is formulated for tear strength is, in my opinion, the most important criterion when selecting a bagging product — it directly correlates to bag life,” says Larry Audette, president of RVB supplier Prairie Technology Group Inc. (Hutto, Texas).

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points out that no matter the specific material, RVBs get heavy when they are built for large parts. Each supplier's material varies in terms of coverage per pound of liquid, but “an RVB for a 10-ft by 10-ft part [3m by 3m] will weigh 60 lb [27.2 kg] or more, which is more than one person can comfortably handle,” she says. “Logistics definitely become a factor. Designing edge frames and lifting points, as you'd use for any B-side countermold, is a great idea to avoid worker injury when lifting.”

Silicone, particularly if it’s improperly processed, can transfer from the bag to parts, but that isn't a problem if the part won’t be finished or painted on the B-side. However, the use of barrier films, such as fluorinated ethylene propylene (FEP), can prevent transfer.

Finally, both silicone and natural-rubber membranes are easily repaired if torn. For the former, Lindstrom recommends the use of an acetocure RTV silicone adhesive, either alone or with an overlaid silicone doubler patch.

**Sprayable Silicone Bags**

Prairie Technology Group was the first to patent a sprayed RVB in 2006 (U.S. Patent number 7014809B2), says Audette. Prairie Technology's Sworl sprayable silicone is distinct from other silicones, he claims, because of its unusually high tear strength. "Our 308 556 product has a measured tear strength of 180 lb [81.7 kg] at a thickness of 0.125 inch [3.2 mm],” he says, noting, “the secret is in the chemistry.” This reportedy makes possible a thinner bag that uses less silicone but is nonetheless strong enough to stand up to the rigors of production without fabric reinforcement.

A reported benefit of the Sworl chemistry is a viscosity low enough that the silicone can be atomized like paint, rather than splattered, and the ability to adhere to itself when successive layers are applied, even when previous layers have cured. "We've eliminated the need to maintain a 'wet edge' when creating a bag,” Audette asserts, adding that a Sworl bag can be created in a morning, then cured and used that same day, although he allows that larger bags might take several days. He adds that Sworl silicone sprayup equipment can be rented by the week, saving the cost of purchasing dedicated equipment.

Prairie Technology offers many edge seal designs, including a perforated style that, when removed after spraying the bag, leaves multiple knobs or bumps that can act as a vacuum channel or resin runner feature (see photos on p. 27).

Smooth-On formulates its own silicone for its RVBs, using raw materials from chemical

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**RVB INSIDER INSIGHTS**

"Commercial fabricators and infusion shops were hungry for knowledge about this technology throughout the past decade,” recalls Keith Charles, technical sales manager at Mosites Rubber Co. (Ft. Worth, Texas). He says, “Training is key.” Charles says there have been many lessons learned while fulfilling orders for vacuum infusion customers that are useful for those who autoclave-cure. Among them is the necessity of building a reusable vacuum bag (RVB) directly on a part or part plug to ensure an accurate fit. “If the bag is too big, you can get wrinkles under vacuum. If it's undersized and not stretched uniformly, and there's any resin backpressure under the bag, you can get bridging that can lead to resin-rich corners or areas in the part.”

Charles also stresses that the RVB thickness must strike the right balance among longevity, economy and weight. “A bag thickness of 0.060 inch [1.5 mm] can work well for an infusion process, and last for an acceptable number of parts,” he notes, but warns, “If you're using the bag in a higher temperature autoclave process with epoxy resin, we recommend at least 0.085 inch [2.2 mm] in thickness” to stand up to higher curing heat, autoclave pressure and epoxy resin chemistry.

Torr Technologies Inc. (Auburn, Wash.) uses Mosites sheet silicone, and sheet materials from other suppliers, to make a wide range of sealed bags for customers who make infused, autoclave-cured parts. Torr’s president, Greg Lindstrom, says Torr also sells cured and uncured sheet stock to customers who want to make their own RVBs. In most situations, he recommends using uncured, high-strength or “B-stage” silicone sheet — that is, silicone that is not fully Vulcanized to form long-chain polymers. Typically, this material is supplied frozen, with a polyethylene backing in thicknesses of 0.063, 0.085 or 0.125 inch (1.6, 2.2 or 3.175 mm); widths of 54 inches/1,350 mm; and lengths of 200 inches/5m. Before use, it’s thawed to room temperature, cut and laid over a part pattern or form.

“We prep the form with a release,” Lindstrom says. “We actually use Dawn dishwasher soap, wiped on, then towed off to leave a very thin film. The uncured silicone sheet, which has the consistency of modeling clay, is then laid over.” He explains that to span parts larger than the width of the silicone, the material edge is pressed down against the form and then skived (tapered) with a sharp knife. A second sheet edge, also tapered, is then overlapped against the first edge, and they are pressed together to form a splice.

“The tapering helps to ensure consistent bag thickness, so that the seam isn’t too bulky.”

Torr Technologies’ RVBs typically include a metal frame around the perimeter to ensure stability and ease lifting. The frame is bonded to the silicone membrane with a room-temperature vulcanizing (RTV) silicone adhesive. V-shaped extruded silicone edge seals are bonded to the membrane below the frame. Lindstrom says that the seal shape “self-initiates” a good seal under vacuum, ensuring vacuum integrity. He recommends a second rectangular or square extruded shape inboard of the vacuum seal. Lindstrom says this extra strip, trademarked as Interflow (see illustration on p. 27), reduces stress on the membrane as it transitions from the frame to the mold surface. Torr adds a similar strip, placed 0.5 inch/12.5 mm inboard of the main vacuum seal, to form a dam that prevents epoxy resin from migrating and attacking the vacuum seal. Not a necessity, B-stage silicone-coated fabric is sometimes integrated into the RVB to stabilize the rubber and increase its hardness or strength. The completed silicone layup is cured in an autoclave at 300°F/149°C for about an hour, then removed from the form and postcured for about four hours. Although the silicone material shrinks slightly (2 to 3 percent) during cure, Lindstrom says the bag’s design takes that into account, resulting in a “perfect” fit. “Curing silicone in this way,” he adds, “ensures a very durable bag ... and many part cycles.”

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CT DECEMBER 2013
suppliers. Because an RVB involves a relatively high cost up front, Frikkers points out that part volume matters: "If you're going to be making 10 of the same part, then the economics make sense." He adds that training is a must for those who transition to RVB technology from consumables, and customers should expect to be trained by their RVB provider.

According to Frikkers, an RVB should be made with four or five layers of material, for a total thickness up to 0.375 inch/6.5 mm. "We recommend a methodical spray pattern, back and forth, then up and down vertically," he explains. "Our two-part silicone is hyper-accelerated for a quick, room-temperature gel without sag." He has also made bags of various thicknesses: "In a bag with thick and thin sections, the thick sections can act as pressure intensifiers for key sections of the part." Fabric can be added for overall reinforcement, but it isn't a requirement, he adds, noting that Smooth-On typically builds a bag with a mesh-type fabric embedded only along the RVB's edges to help support placement of the vacuum channel and ports. He claims that one of Smooth-On’s marine customers has used the same RVB for about 800 parts. Another Smooth-On recommendation, depending on bag size and weight, is to add hard anchor points along the bag margins, integrated with cloth reinforcement, so the RVB can be safely and easily lifted with an overhead crane.

A silicone RVB champion, Harper maintains they "are much less expensive in terms of labor and materials to produce than conventional RTM or light RTM counter-molds." His company’s fRST RVB system uses ACC Silicones’ VBS 26 formulation. "In our experience, it is made to higher consistent specification than others I’ve worked with," he maintains. The material is applied with Harper’s SilCon silicone spray equipment and edge seal/vacuum ancillaries. Harper offers two additives — one can be used to produce a thixotropic paste, and the other is a pot-life extender that lengthens the current eight-minute mixed pot life to as much as 90 minutes. Harper claims the typical time to make a 3 ft by 3 ft (1m²) multicurvature RVB with built-in edge seals and vacuum ports is a mere 70 to 90 minutes, and the resulting RVB can be used in production within 30 minutes and will last 500 part cycles.

Harper says that, in his experience, RVBs make it safer to load fiber reinforcements into the mold because the operator can adjust precisely the fiber edge after the layup is in the mold and the bag is down by simply lifting it to inspect the local edge detail, without having to lift an entire rigid mold. This results in virtually zero waste or flash at the molded edge, he says.

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Finally, a fire retardant FRP with unmatched processability.
Examples of edge seals for RVBs. Note the adhesion-promoting tissue embedded in the MVP Locking Lip Seals (top right). The “bumpy” seal (bottom right) from Prairie Technology Group’s Sworl product line is of silicone, sprayed over the perforated foam “tool” (middle right), then removed. The cross-sectional images (above) show an elastomeric membrane with metallic frame, attached edge seals, and Torr Technologies’ Interflow strip and resin dam, which protects the vacuum seal from part resin.

tear strength and longevity, especially for parts with sharp features. Her company sells a nonwoven polyester in strips that are precut to fit the customer’s RVB design. Duncan recommends a bag thickness of about 0.120 inch/3 mm, built up in four or five layers, with the fabric exactly in the vertical center so an equal thickness of silicone lies over and under it. Composites One also sells extruded and reusable wax strips, usually a half-round design, that can be used to create a vacuum channel around the bag perimeter and resin channels (if needed) to facilitate resin flow. Hand-operated silicone cartridges are also available for smaller molds.

MVP’s communications specialist Susan Murphy explains that MVP developed, with the help of Light RTM/infusion technical specialist Charles Tur, the Flex Molding Process. Introduced in 2010, the system is billed as more than a reusable “bag.” Murphy says its combination of a dispensing system able to process either silicone, latex or polyurethane as well as multiple injection systems with integrated accessories “instantly elevates the infusion process from the ‘traditional’ bucket method to fast and efficient and automated.”

The system’s reusable silicone membrane (see photo, p. 25) is a two-part formulation applied with MVP’s trademarked Patriot Duo 1:1 silicone system. A reinforcement called Flex-Cloth adds strength and integrity and reduces the amount of silicone needed to build overall thickness. This cuts the finished bag weight (the membrane materials are heavier than the cloth) and “reduces the tendency of the membrane to stretch over time, which improves longevity and reduces tears,” says Murphy.
As an alternative to spraying, RVBs can be made with high-strength silicone sheet goods. In this photo, the gray material is a peroxide-cure, opaque silicone; the white translucent material is platinum-cure silicone.

MVP’s system includes patent-pending silicone perimeter Locking Lip seals and resin channels, which are embedded with a tissue that ensures adhesion between the seals and the membrane material. Suction cups are added to the Locking Lip seal to ensure the membrane stays locked in place during the vacuum cycle, which is most helpful with larger or deep-draw part molds.

One of MVP’s hundreds of customers, French auto aftermarket manufacturer Durisotti (Sallaumines, France), started using the Flex Molding Process in 2011 to make a 160-ft²/14.9m² composite floor panel that replaced a utility van’s factory-built floor. Previously, the part was infused with a consumable bag at a rate of one per day. After attending a demonstration, Durisotti made the switch.

After three days of training with Tur, Durisotti was able to mold the part using a silicone membrane (see photo, p. 26). Since then, Durisotti has made 10 more membranes on its own. The production rate has tripled, and the company expects further improvements, says Durisotti’s Composites Workshop R&D manager Jean Michel Kosowski: “The quality of the part … is better, there is time savings compared to classic infusion, we have no risk of vacuum leaks, quality is consistent, part-to-part, and we have the capacity now to increase daily part production per mold.” And, reports MVP, Durisotti has produced more than 700 parts using one membrane.

GREEN RVBS — WITH NATURAL RUBBER

A pioneer of spray forming RVBs with modified natural rubber elastomers, SR Composites’ system is formulated for elevated service temperatures and reportedly exhibits increased tear strength and eases spraying of void-free films. “The average tear strength of natural rubber typically exceeds silicone rubber by a factor of three, at a tenth of the gas diffusion rate, so a 40-mil Sprayomer membrane can provide desired performance with no reinforcement,” claims Rydin. The available elastic deformation of this more flexible construction reportedly can be realized with only atmospheric pressure acting on the evacuated membrane, and it is said to conform well to the preform under vacuum alone.

A membrane is typically built up with 10 to 15 spray passes over an unreleased part or mold using the company’s Quickmold spray equipment, which can be leased. The transition from liquid film to
elastic membrane can be completed during several 15-minute convection oven dwells at 140°F/60°C and typically needs less than 24 hours to fully cure.

In terms of part release, SR’s Robert Scrima says users should treat the natural rubber RVB like an extension of the part mold: “Very few shops would use a green mold without some treatment first — treat the Sprayomer bag like you would hard tooling.” He adds that most semipermanent release systems will provide from 10 to 25 part cycles, depending on the resin used.

Like other suppliers, SR Composites boasts a long list of customers who have adopted Sprayomer RVBs. A standout is D&T Fiberglass (Sacramento, Calif.), one of the largest producers of fiberglass food-transport containers in the country and a specialist in agricultural transport tanks. John Schwitalla, senior design engineer, says D&T is transitioning to RVB from polyethylene terephthalate (PET) films: “We will never go back to classic infusion using consumables,” he maintains. “The RVBs have already paid for themselves, setup requires less labor, we’ve reduced our waste stream and we’re seeing significant cost reductions.” He also points to shop emissions reduction, which is critical in environmentally aware California.

Because the tanks are produced on a male mold, with a U.S. Food and Drug Admin. (FDA)-compliant gel coat on the inside, RVBs have greatly simplified mold setup for these large, complex parts: “It works brilliantly,” adds Schwitalla.

D&T investigated several approaches and decided on Sprayomer, in part because the membrane has to be quite thin (0.04 inch/1 mm) to keep weight to a minimum, due to the large part size. Schwitalla says that for his company’s process, natural rubber resists tearing better than silicone.

**GROWTH SECTOR**

Although RVB suppliers believe fervently in their own products, they agree that RVBs generally provide a means for cleaner, more cost-effective molding of production parts. They also concur that RVBs pay for themselves in as few as 10 molding cycles. According to Rydin, a single-use nylon film bag appears to cost a fraction of the upfront price per square foot of an RVB, but users need to estimate a return on their total investment and evaluate whether their production numbers support switching from consumables: “Lower operating costs, expanded capabilities and improved product consistency make RVBs affordable and sustainable.”

The growth of RVB usage might be indicated by the large number of nondisclosure agreements (NDAs) that prevented CT from describing many more case studies for this article. Lindstrom says, “We have seen huge growth in the use of RVBs.” In the end, virtually every source has the same opinion: RVB technology is an area that every infusion shop should investigate. Harper concludes, “The current market indicates that RVBs are indeed game changing and the answer for many applications.”

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Read this article online | http://short.compositesworld.com/4dLJg8tA.

RVB material providers offer onsite training and video resources. The latter include the following:

- Prairie Technology: http://www.sworl.net/videos.html
- SR Composites: http://srcomposites.com/newmovie.html
- MVP: http://www.youtube.com/watch?v=XYvfQHrQZlgM, and for the Flex Molding Process: http://www.youtube.com/watch?v=iGBN_850eIA.

Read "RVB infusion = Light RTM?" online at http://short.compositesworld.com/sDUgbrF2.

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That Bayerische Motoren Werke AG (BMW, Munich, Germany) has stirred up a hornet’s nest of anticipatory buzz within the carbon fiber composites community comes as no surprise. The recently introduced BMW i3 electric commuter car’s carbon composite passenger safety cell (see image and caption on opposite page) tips the scale at a mere 310 lb/140 kg. With annual production volumes targeted at 30,000 vehicles, the i3 is the largest-volume production car ever to make such extensive use of carbon fiber-reinforced plastic (CFRP).

And at that production level, the i3 alone could consume more than 9.6 million lb/4,355 metric tonnes of finished CFRP structure each year.

These facts and figures, however, must be put in perspective. The i3 is one of approximately 100 vehicle models manufactured around the world that feature at least some standard equipment (that is, not special-order items) made from carbon composites. Many of them are niche luxury vehicles and supercars or million-dollar hypercars. Together they consume an estimated 11 million lb (4,990 metric tonnes) of CFRP structures annually worldwide. The low-volume i3 program over two or three years will almost double the global automotive CFRP requirements. That begs the question: How many programs similar to the i3 would it take to create a revolution in the
advanced composites industry? Which leads to another question: Is the auto industry at this tipping point?

A number of blogs and op-ed columns, at the CompositesWorld.com Web site and elsewhere, have traced a long history of similar anticipation, dating back to the late 1970s and early 1980s. Carbon fiber professionals have said that the history of advanced composites is littered with the bodies of true believers. Fellow CT contributor and consultant Dale Brosius has noted that, despite his many efforts, “carbon fiber is a material of last resort,” and then only as a means to improve fuel economy. But evolving rules in the U.S. and European Union that govern fuel efficiency and CO₂ emissions are means to improve fuel economy. But evolving rules in the U.S. and European Union that govern fuel efficiency and CO₂ emissions are forcing OEMs to rethink their reluctance to use CFRP, and that fact might — as the data in this outlook demonstrates — limit the body count of true believers this time around.

AUTOMOTIVE MATERIALS PRIMER

But first, let’s look at the big picture. According to the International Organization of Motor Vehicle Mfrs. (OICA, Paris, France), the global automotive industry produced about 63 million passenger vehicles and 21 million commercial vehicles in 2012. Over the remainder of this decade, the annual production could grow to 100 million vehicles per year, with China accounting for about 18 to 20 percent of the total production and demand. More than 100 OEMs supply these vehicles and offer approximately 1,500 models. The typical passenger vehicle curb weight ranges between 3,000 and 4,000 lb (1,364 and 1,818 kg). The weight of sport utility and crossover utility vehicles (SUVs and CUVs) is generally higher, by 500 to 1,000 lb (227 to 454 kg). By material type, their mass breaks down as shown in the chart on p. 32.

Some quick math tells us that each year more than 300 billion lb (136 million metric tonnes) of new cars and trucks are put into service around the world. For the production of these vehicles in 2012, OICA estimates the steel industry delivered approximately 240 billion lb (108.86 million metric tonnes) to automobile OEMs. The Aluminum Assn. (Arlington, Va.) estimated that 2012 automotive aluminum shipments totaled approximately 16 billion to 17 billion lb (7.26 million to 7.71 million metric tonnes). By way of comparison, the total composites volumes associated with these passenger vehicles represents a market of roughly 250 million lb (113,430 metric tonnes). That’s just shy of 1 percent of the total estimated material weight delivery. During 2013, the CFRP volumes delivered to automotive OEMs are expected to reach nearly 16.5 million lb (7,484 metric tonnes), about 6.5 percent of automotive composites and a miniscule 0.05 percent of the total global automotive material requirements.

COMPLIANCE-DRIVEN AUTO DESIGN (R)EVOLUTION

Against that somewhat humbling background are some present and unpleasant realities for the auto industry. OEMs need to make some big changes to their vehicle lineups over the next 12 years if they hope to achieve the ever more stringent fuel efficiency and emissions standards that are being enacted around the world (see “Learn More,” p. 35). With iterative improvements over this time period, automakers have a number of milestones to reach, and the penalty for missing them increases each year. Given greater international competition, automakers have reduced vehicle design cycles from about nine years to six or seven years, which gives them two full design cycles in which to develop solutions before 2025. So how will automakers achieve compliance?

From a brand and vehicle lineup perspective, an OEM could boost its corporate-wide fuel efficiency by selling more small and efficient vehicles in place of larger ones. Aston Martin (Gaydon, Warwickshire, U.K.), for example, recently introduced its Cygnet, a $49,500 upscale version of Toyota’s (Aichi, Japan) $15,500 subcompact city car, the iQ. Market reception of the Cygnet has been extremely weak because it is the polar opposite of BMW’s marque performance brand. In the large sedan category, the OEM can downshift the size of its vehicles or eliminate larger models. Indeed, Ford Motor Co’s (Dearborn, Mich.) successful Crown Victoria and General Motors Co’s (Detroit, Mich.) Caprice, at least temporarily, have gone the way of the dodo bird — making room for smaller, more exciting products.

A second tack is to sacrifice some performance in favor of greater fuel efficiency. This seems likely for moderately priced models because horsepower and torque ratings for most vehicles have increased 25 to 50 percent over the past decade. Reversing that trend with smaller, high-efficiency gas or diesel engines is relatively easy and, therefore, can reduce the cost of achieving a higher overall miles per gallon equivalent (mpge). However, this strategy would be anathema to consumers of luxury and performance vehicles.

In fact, neither of these paths to better overall fuel economy, despite their merit, will have much appeal for OEMs that specialize in high-end luxury vehicles. What is clear, however, is that the electric drive and the carbon fiber passenger cell of the BMW i3 represent a huge leap in strategy for the company and, at about 310 lb/140 kg of CFRP per copy, it is one of the biggest consumers of CFRP in the world.
in luxury automotive brands. More importantly, even those whose production lines roll out large numbers of the smallest cars on the road will need to address more broadly the physics of fuel economy.

Toward that end, one piece of low-hanging fruit is to reduce vehicle rolling resistance, the measure of friction or energy loss where, literally, the rubber meets the road. As a general rule, the heavier the vehicle, the greater the rolling resistance. Over the past decade, consumer aesthetic preferences have favored larger, heavier wheels (along with larger cars). One strategy is to equip vehicles with high-pressure (50 psi) tires. Although they are more expensive, they can reduce rolling resistance by 25 to 35 percent. For most cars on the road, reverting to smaller-diameter wheels with high-pressure tires would provide small but notable benefits. This could be acceptable to most automotive consumers, but aficionados of luxury and performance vehicles would find the loss of road grip and style a bitter pill.

Aerodynamics is another way to enhance vehicle efficiency, especially at freeway speeds. Reducing vehicle wind resistance requires a two-pronged strategy: reducing the car’s frontal area (a product of the car’s height and width) and its drag coefficient. Obviously, there are limits to how far height and width can be shaved without sacrificing occupant space and safety. The drag coefficient for most passenger cars ranges from 0.35 to 0.20 (the lower the drag coefficient, the better), and it has remained fairly steady for the past 15 years. Some tricks, such as the louvered grills in the Ford Fusion Titanium editions and better use of underbody fairings can make general improvements, but substantial innovation based on the common four-wheel layout is limited.

Power plant reengineering is a more promising area of research. Hybrid-electric and plug-in electric vehicles already show substantial gains over their straight internal combustion engine (ICE) counterparts. ICE efficiencies can be gained through turbochargers and improved air intake to the combustion chambers. Valveless engine combustion chambers and novel engine architectures also reduce internal engine friction, but they are either technically and commercially premature, or they’re governed by patents that reduce their potential for widespread adoption. Reducing internal friction in transmissions and other key components also can improve overall efficiencies. On the whole, increasing powertrain efficiency could contribute as much as 25 to 35 percent of the sought-after improvements between now and 2025.

**NO ROOM FOR HALF MEASURES**

But these measures, all good, are still not enough. The 600-lb gorilla in the room is vehicle mass. Of all the factors that influence vehicle efficiency, mass is the most influential and reducing mass need not involve significant sacrifices in the realm of driver/passenger comfort. In fact, for hybrids and plug-ins, weight reduction is critical to achieving driving ranges comparable to traditional ICE-powered vehicles. Virtually every new car introduced to the market will have to go on a weight-loss plan.

Every 100-lb/45-kg reduction in weight is said to improve fuel efficiency by roughly 2 to 3 percent. From a vehicle design perspective, however, a 100-lb/45.4-kg reduction in one area sets up the potential for further weight reduction in a variety of other components and systems — resulting in a virtuous spiral of lower weights. Vehicles with all-composite bodies-in-white (BIW) could weigh 50 to 70 percent less than a steel BIW, netting about 250 lb/113 kg in savings. And the virtuous spiral would permit engineers to downsize engines, transmissions, brakes, suspension members, batteries and more, potentially reducing vehicle weight by an additional 300 lb/227 kg!

Although CFRP promises extreme weight savings, there are competing factors that limit its potential in vehicle applications. Foremost is cost. CFRP is roughly 10 times more expensive to manufacture than aluminum and magnesium,
and it’s even more costly than advanced high-strength steels and glass fiber-reinforced plastics. Equally challenging is productivity. Despite the recent advent of snap-curing thermoset resins, less costly out-of-autoclave processing and the alternative of thermoplastic matrices, which have driven down cycle times from eight hours or more to about 10 minutes, cycle times still limit CFRP’s uses to models produced in volumes of 40,000 or fewer vehicles per year.

Another factor is end-of-life regulations. Metals are readily recycled, but the same cannot yet be said of CFRP (see “Learn More”). This leads to higher relative material costs, landfill expenses and further exposure to fines in some regions. The time, expense and limited availability of CFRP repair services present further obstacles and the potential for higher insurance rates. Given these concerns, auto OEMs have opted for less risky and less expensive solutions and will continue to do so unless they are driven by other economic considerations and model brand appeal.

In CFRP’s favor, building automobiles that comply with corporate average fuel economy (CAFE) and emissions standards will require adoption of all the previously mentioned strategies. Advanced high-strength steels, aluminum and magnesium are material solutions that will work for the majority of vehicles entering the market. It is in the uncompromising world of luxury cars that the need for mass reduction will loom most large and the additional cost of weight-loss strategies can be most easily absorbed. In this market space, then, CFRP will find its greatest opportunities.

DEMAND FOR AUTOMOTIVE CFRP

The previous discussion of the road to vehicle efficiency and the material opportunities and barriers along the way indicates that during the next 10 to 15 years carbon fiber will not be in everyone’s carport. New vehicle applications appear to be limited by processing speed and costs, with most opportunities in applications serving models produced at volumes of less than 40,000 vehicles per year and sold at a price in excess of $60,000 — the i3 is an outlier to this general guideline. With this in mind, let’s look at the market for these types of vehicles.

Global passenger-vehicle and light-truck production currently totals about 63 million units annually. Of this total, luxury autos account for about 9 percent. Making up these 6 million cars are approximately 210 models, representing a wide array of body styles and layouts, including compact coupes and sedans, midsize vehicles, large passenger vehicles, luxury trucks, and SUVs and CUVs. Somewhat surprisingly, about 100 current or anticipated new models make use of CFRP — nearly four times as many as 10 years ago!

Based on available information about these vehicles and some more moderately priced sports cars and SUVs that also will incorporate CFRP, we estimate that the total weight of CFRP components will grow from 16.5 million lb (7,486 metric tonnes) in 2013 to 36 million lb (16,334 metric tonnes) in 2016. After factoring in the CFRP applications that auto OEMs have announced for the next three years (“identified composites volumes”), anticipated or “potential new models” over the following seven years and some notional accounting of a small number of “unaccounted supercars” and “unaccounted luxury sedans” that are not included in our analysis, the accompanying graph (above) shows that by 2022 the total weight of carbon composites going into cars annually could exceed 100 million lb (nearly 453,600 metric tonnes). This indicates that CFRP manufacturing will grow dramatically and will augment expanding opportunities for other composites and lightweight metals.

To support the manufacture of 100 million lb (45,360 metric tonnes) of finished CFRP parts, the automotive supply chain will require nearly 95 million lb (39,225 metric tonnes) of raw carbon fiber. Today the auto industry (including race car teams and aftermarket accessory vendors) consumes about 3.5 percent of the global carbon fiber production capacity. According to this outlook, by 2022, that could grow to nearly 25 percent.

Given the number of companies looking to expand their current automotive composites business and those that are considering entry into the market, it is not enough to say that volumes are growing. It is important to understand what applications are driving this change. Composites Forecasts and Consulting (Mesa, Ariz.) has recently released a market report that details related activity within the supply chain. Based on the published data, it is estimated that in 2013, nearly 2.25 million individual composite components will have been fabricated and delivered to OEMs. These components are in production at 35 companies around the world, with about 70 percent of the volume coming out of Europe.

Composite components are included in virtually all facets of a vehicle’s design, including:

- Chassis members
- Body panels and exterior accessories
- Structural and cosmetic interiors
MARKET OUTLOOK

When processing composite material, successful removal from the mold is critical to achieving higher quality, lower cost and boosted operational efficiency.

Suppliers that build chassis, body panel, brake rotor and driveshaft components are currently the largest consumers of CFRP materials and will continue to drive growth over the forecast period. Combined, these components account for 87 percent of the identified component volumes and 95 percent of the identified delivered material weight. The Composites Forecasts and Consulting report noted, however, that current improvements in vehicle drivetrains and aerodynamics, as well as weight reduction, will not be enough to meet the 2025 emissions targets, which opens the potential for some of the other application sectors previously listed here.

In the past year, for example, carbon fiber wheels have appeared on high-end

| 2012-2025 CAFE standards by model year, miles per gallon equivalent (mpge) |
|-----------------------------------|------------------|------------------|------------------|------------------|
| Model Year | Passenger Cars | Light Trucks | Passenger Cars | Light Trucks |
|            | "footprint": 41 ft² (3.8m²) or smaller | "footprint": 55 ft² (5.1m²) or bigger | "footprint": 41 ft² (3.8m²) or smaller | "footprint": 75 ft² (7.0m²) or bigger |
| 2012       | 36              | 28              | 30              | 22              |
| 2013       | 37              | 28.5            | 31              | 22.5            |
| 2014       | 38              | 29              | 32              | 23              |
| 2015       | 39              | 30              | 33              | 23.5            |
| 2016       | 41              | 31              | 34              | 24.5            |
| 2017       | 44              | 33              | 36              | 25              |
| 2018       | 45              | 34              | 37              | 25              |
| 2019       | 47              | 35              | 38              | 25              |
| 2020       | 49              | 36              | 39              | 25              |
| 2021       | 51              | 38              | 42              | 25              |
| 2022       | 53              | 40              | 44              | 26              |
| 2023       | 56              | 42              | 46              | 27              |
| 2024       | 58              | 44              | 48              | 28.5            |
| 2025       | 61              | 46              | 50              | 30              |

When There's No Room for Error...

When processing composite material, successful removal from the mold is critical to achieving higher quality, lower cost and boosted operational efficiency.

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From wind blades and boat hulls to aircraft parts and racecar bodies, we understand composite processing. We spend thousands of hours on composite production floors, giving our technical and manufacturing experts unmatched insight into the toughest production challenges. In our world-class, industry-dedicated laboratories, we apply this insight to developing proven Chemlease solutions for successful de-molding.
sports cars, such as Koenigsegg Automotive AB’s (Ångelholm, Sweden) Agera and the more affordable F-Type series from Jaguar Land Rover Ltd. (Whitley, Coventry, U.K.). Composite seating also seems to be an application with considerable potential, and suspension components appear to be a near-term target, including leaf and coil springs. Further, other suspension components, including sway bars and suspension arms and frames, could be supported with existing filament winding and resin transfer molding (RTM) processing techniques, cutting by two-thirds the weight of these components compared to today’s metal versions. OEM use of these emerging components is expected to grow about 600 percent over the forecast period, and they present many additional opportunities for aftermarket suppliers.

As this outlook makes clear, a great many factors have had an impact on why and how carbon fiber composites made their way into the automotive industry and how those inroads will continue into the future. To be sure, there will be challenges for the composites industry to overcome if it is to compete in this marketplace. Chief among them are cost and scalability. Over the next few years, a few notable examples of critical composite structures for mass-production automobiles will hit the streets. The impact of these relatively small-volume production models will create a huge but relatively isolated impact on the demand for CFRP goods and services. During the remainder of this decade, we are likely to see a small number of additional luxury cars and sportscars join the fray — again with relatively high impacts on the advanced composites supply chain.

Given the preceding discussion, it could be too early to claim that CFRP will displace traditional materials in automobiles to the extent that it has in aircraft, but it’s fair to say that the signs are pointing in that direction. As noted earlier, there are almost two full vehicle design cycles between now and 2025. There is plenty of time for auto OEMs and the composites supply chain to figure out how they, together, can make the most of this automotive opportunity. [CT]
A marriage of design and manufacture

Architectural design studio and boatbuilder cooperate to make this passenger terminal “first” a first-class showpiece.

As more architects learn about composites and dabble with their application in building and construction, composites fabricators the world over will increasingly face the sometimes daunting task of turning a creative design into a real, feasible and manufacturable structure. Doing so requires teaching, additional creativity, adaptability and trial and error.

Such was the case at the Union Station bus terminal in Washington, D.C., when the decision was made in 2011 to remake the many-years-old — and drab — passenger concourse into a modern, inviting, accessible and efficient space that would help guide passengers from one mode of transport to another.

The centerpiece of the Union Station renovation is a silver and bright yellow ticketing and information pavilion on the concourse. It weds ultracreative structural design with a composites manufacturing strategy that drew, incongruously, on lessons learned from years of traditional boatbuilding methods adapted for this new application. The result is not only a refreshed bus terminal concourse, but also an emerging iconic symbol that marks arrivals and departures for thousands of Washington, D.C., travelers.

BUSES AND MORE BUSES

Union Station, located just north of the U.S. Capitol, began operation as a train station in 1907 and grew quickly to become the city’s transportation hub. Its neoclassical design was a hallmark of Washington, D.C., architecture for decades. However, competing transport options — cars and airplanes — eventually diminished the station’s standing. In the 1970s, a parking garage was attached to the north end of the station, over the train tracks, with a utilitarian design that featured liberal use of concrete, as might be expected in a parking structure. In the 1980s, the U.S. government renovated the building and made it, once again, a centerpiece of rail transportation and local commerce.

Meanwhile, after decades of steadily declining interest, cost-conscious travelers who were wary of flying and disinterested in driving rediscovered the benefits of intercity bus travel. Indeed, since 2006, intercity ridership has increased each year, spawning new operators, new routes and new amenities. Greyhound, BoltBus, Coach USA, Megabus and others saw passenger traffic increase 7.5 percent from 2011 to 2012, the largest increase among all modes of travel.

Many intercity bus operators still deposit and pick up passengers at various locations from city to city, often at designated curbside locations where shelter, amenities and information are usually scarce. For travelers, this occasionally makes bus travel tenuous and uncertain.

Faced with this haphazard approach to intercity bus arrivals and departures in Washington, D.C., the Union Station Redevelopment Corp. (USRC) decided in 2010 that it would consolidate all inter-
city travel activity on the second level of the station’s parking garage. This would place all of D.C.’s intercity bus and rail service at a central, enclosed location, increasing passenger convenience. This would require new information, ticketing and passenger-waiting facilities for bus passengers. The perfect location for these amenities would be the passenger concourse that connects the original structure with the parking garage, a large area bisected by escalators and partially exposed to the elements. The trick, then, was to transform this concrete landscape into an inviting passenger transit area.

ENTER THE ARCHITECT

USRC contracted with Studio Twenty Seven Architecture (S27, Washington, D.C.) to design bathrooms, a concourse waiting area and a ticket and information pavilion. Todd Ray, one of the principals of S27, says his firm developed several design options for the space, with much of the design variation focused on the location, size and shape of the pavilion. The long, narrow concourse would limit the structure’s size, yet whatever was developed would have to be accessible, inviting and able to withstand exposure to sun, wind, rain and snow. And it would have to be designed and constructed quickly; the design work started in February 2012, and the finished pavilion was to be installed in May of this year.

Ray says USRC latched on to a “twin pavilion design” that joined two ovoid structures into a single “Booleaned ellipsoid” (see the photos on this spread). It was decided that the unusual shapes would be fabricated in strips or peels. The conjoined structures, gel coated yellow and silver, would feature what Ray calls a “collapsing of skin,” where arched roof panels placed over a skeletal frame would slope to the ground and become the pavilion’s walls. Each pavilion would feature an entrance for easy access by bus passengers.

The question was, What materials should be used? At first, metals were considered, but cost considerations steered the architect toward a mix of metals and nonmetals. Then, says Ray, in conversations with the project’s contractor, Monarc Construction Inc. (Falls Church, Va.), the pavilion’s curved structure suggested the possibility of turning to a boatbuilder, and that’s when composites entered the picture. Several boatbuilders were evaluated for the project before S27 and Monarc chose Compmillennia LLC (Washington, N.C.), led by general manager Jim Gardiner. With a long history of manufacturing composite yachts, Gardiner saw the ellipsoid pavilion as an inverted boat hull — albeit one with some significant variations.

“We’d never used composites before,” Ray recalls. “This was totally new for us, but it was an enjoyable learning curve.”

BALANCING IDEAL AND REAL

The first task, says Gardiner, was for Compmillennia to assess the design and make two critical judgments about project feasibility, in regard to manufacturability and cost. Compmillennia was aided in this effort by Eric Greene Associates (Annapolis, Md.), which performed wind/snow load analysis on the pavilion and provided composite design help. The original design, he says, came in as two separate pavilions, one the inverse of the other, but each expected to come from the same mold. This concept proved prohibitively expensive, so the plans were modified. After further cost evaluation, balanced against square footage requirements, S27 decided to alter the design further by slicing the ovoid shapes vertically to create a flat, textured wall at each entrance of the pavilion and along its back wall. Gardiner says the resulting design looked like a “zeppelin with the ends sliced off.” These vertical walls, it turned out, would prove to be the most challenging aspect of the project.

Another challenge was the arched roof and wall system. Given the inverted-hull look, Gardiner suggested the use of a slip mold, on which a section of the structure is molded and moved or “slipped” off the mold so that the next section can be molded. Ray and S27, however, sought a roof that consisted of a series of interlocking flat, narrow panels arching across the length of each pavilion segment.

“The difference between the monolithic versus the segmented roof evolved based on cost modeling of systems,” Ray says. “The segmented scheme could be made from a few templates/formworks and clipped together. In addition, the seams added a sense of scale to the structure thus making it more visually measured and comprehensible to the passer-by.”

Finally, there was the question of time. Compmillennia initially had 72 days to build the pavilion, but paperwork delays trimmed the production window to 32 days. Gardiner recalls. “I was told by the general contractor that if the pavilion was not delivered on the date it was due, don’t bother bringing it up.”

MORSE CODE MEETS FIBERGLASS

First, Compmillennia attacked the flat wall panels. On the original design, says Gardiner, they featured a texture that resembled...
The entire flat wall panel layup, consisting of plies of CSM, biaxial E-glass, PVC core and polyester matrix resin, is bagged for cure.

The flat wall panel, fully gel coated and ready for laminate build-up.

A close-up of the finished wall panel, bearing the Morse coded lyrics to the Death Cab for Cutie song “Soul Meets Body.”

Pavilion ceiling panels, flanged on one side, are layed up on molds. Altogether, 50 ceiling panels were molded, each uniquely designed and sized for a specific location on the structure.

Compmillenia produced one panel per mold per day for the pavilion roof. Smaller panels were produced more quickly.

Assembly of the pavilion begins with erection of the end panels.

The ribs over which the roof panels will be layed are secured in place. Some of the ribs attached to the end walls and some, as shown here, arch down to the floor.

Roof panels are placed over the ribs, adhesively bonded and secured.

This inside view shows the ribs, with panels overlaid. Panel flanges are attached to the ribs with L-shaped fiberglass fixtures.

Roof panel flanges intersect ribs at 90°.

The pavilion was assembled in two halves to ease transportation. They were delivered to Union Station and installed overnight on May 1, 2013.
the surface of water. Then, says Ray, Studio Twenty Seven shifted gears, seeking a more iconic and meaningful design that conveyed a message. “We wanted something less random, something imbued with meaning,” Ray remembers.

“The real fun started with the end walls,” says Gardiner. “At first, it looked like splashes of water on a panel. Then they came through with the Morse code.” Indeed, S27 decided to etch on the panels, in Morse code, lyrics from a song by the group Death Cab for Cutie, called “Soul Meets Body.” The lyrics of interest, says Ray, convey the sense of impermanence and transience that is a bus depot:

’Cause in my head there’s a Greyhound Station
Where I send my thoughts to far off destinations
So they may have a chance of finding a place
Where they’re far more suited than here

The coded lyrics were routed by signage fabricator Smart Design Inc. (Woodbridge, Va.) into several sheets of 4-ft by 10-ft (1.2m by 3m) medium-density fiberboard (MDF). Six sheets were then laid out and pieced together into a big 10-ft by 24-ft (3m by 7.3m) panel. The trick, says Gardiner, was to get gel coat into the Morse code dimples in the MDF without destroying the tool or the part. “Maybe it’s been done before,” says Gardiner, “but I hadn’t seen it, so we had to make it up.”

MDF is porous, so a film was required to coat the tool surface, hold the vacuum while it was sucked into contact with the routed design and then release the finished part afterward. Gardiner turned to a marine-industry staple for a solution: the white plastic wrap used to cover boats for protection from weather. This 6-mil thick plastic film, Gardiner says, responded well to the vacuum and conformed well to the Morse code dimples.

Compmillennia covered the entire tool with this film and then pulled a vacuum on a section of its 20-ft by 80-ft (6m by 24.4m) vacuum mold table to about 100 millibars (22 to 25 inches Hg) absolute pressure.

“This was a high-risk strategy,” Gardiner reports, “because if you lose the vacuum, you lose the part.” Testing, however, revealed that it could work.

With a tooling strategy in place, the next step was to spec the gel coat. S27 had specified a custom yellow color that had to be matched exactly. This yellow, it turned out, is the same color as the paint used for parking lot lines — more symbolism from the parking structure. Working with HK Research Corp. (Hickory, N.C.), Compmillennia developed a yellow gel coat that won approval. A release agent was sprayed over the MDF tool after the plastic film was placed, mold plants for windows and doors were placed, and then the gel coat was applied at a thickness of 18 to 22 mils. This was followed by application of ATC Scott Bader’s (Burlington, Ontario, Canada) Poly-Bond B55LV, a polyester-based material that was squeegeed into the Morse code dimples to create a flat surface on which the rest of the panel structure could be placed. From there, fabrication of the panels was relatively simple. Stacks of fiberglass and resin were added to build the structure’s
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final 1.625-inch/41-mm thickness. The laminate included the following materials, in this order:

- 1.5-oz chopped strand mat (CSM) from Owens Corning (OC, Toledo, Ohio)
- Fire-resistant K130-PTJ-20 polyester resin from AOC LLC (Collierville, Tenn.), hand rolled at ambient temperature and cured for four hours
- 1.5-oz CSM (OC)
- E-LT 3200 0/90 stitched biaxial E-glass fabric from Vectorply (Phenix City, Ala.)
- K130-PTJ-20 polyester resin (AOC)
- 30-mm/1.2-inch Divinycell polyvinyl chloride (PVC) foam core from DIAB Sales Inc. (DeSoto, Texas)
- 1.5-oz CSM (OC)
- E-LT 3200 0/90 stitched biaxial E-glass (Vectorply)
- K130-PTJ-20 polyester (AOC)

Comp millennia finished the panel with a 7-inch/178-mm wide flange along what would be the wall’s base to provide attachment points for securing the pavilion to the concourse floor during installation. Gardiner says that because it was so large, the entire panel was kept on the heated mold table under an insulation blanket as long as possible, and at as consistent a temperature as possible, to avoid warping.

**PANELS AND SKELETON**

As attention turned to the pavilion roofing system, the challenge centered on the fact that each panel, because of its location and length, has unique dimensions. Each panel, therefore, had to be built to a different specification for its location in a particular place on the pavilion.

Fabrication of the panels relied on a tried-and-true method, namely lofting full-size patterns. Digital files of the panels were sent by S27 to Compmillenia, which used the files to cut panel patterns from long sections of floor paper. These paper patterns were placed on a mold and used as a guide for material placement. The stack for each 0.25-inch/6mm thick panel includes a clear gel coat and a dark silver gel coat (both provided by HK Research), a 1.5-oz CSM (OC), two layers of E-LT 3200 0/90 stitched biaxial E-glass (Vectorply), and K130-PTJ-20 polyester (AOC). Each panel is flanged along one edge to provide a mating surface for the adjacent panel. (“We wanted flanges on each edge,” Gardiner says, “but we didn’t have time to do that.”) Gardiner says Compmillenia could produce one large panel or multiple smaller panels per day from each of the two molds manufactured for the job.

Eventually, the panels were draped over and bonded to a fiberglass skeleton consisting of a series of L-shaped ribs that formed arches from one side of the pavilion to the other. Some of the ribs were attached to the yellow end walls, and others continued down to the groundsill plate. Each rib features a 4-inch/102-mm web abutting a 3-inch/76-mm flange, all fabricated by hand with four layers of Vectorply’s E-LT 3200 E-glass and OC’s K130-PTJ-20 polyester. The flange on each panel
intersects a rib at a 90° angle and is attached via adhesive with an L-shaped fiberglass fixture. Joints between each roof panel were secondarily bonded with Vectroplly’s E-BX-2400 fiberglass. Seams between the panels were sealed with architectural-grade caulk to keep out moisture and other elements.

INSTALLATION

The pavilion was fabricated in two sections at Compmillennia’s plant in Washington, N.C., and shipped by Deep Water Transport Enterprises Inc. (Washington, N.C.) via flatbed truck to Washington, D.C., for installation at Union Station. Because the station is heavily used, and because of limits imposed by other ongoing work in the garage, there was a very narrow window in which Compmillennia could deliver and install the pavilion: the night of May 1, 2013.

Gardiner supervised the effort and says the structures’ low mass made them relatively easy to unload, move and position on the concourse (see “Learn More,” below). The next several days were spent bonding and securing the halves of the pavilion together, anchoring the pavilion to the floor, installing doors and prepping the structure for internal finishing.

Looking back, Gardiner and Ray agree that cooperation between Compmillennia and S27 was the key, supported by constant and well-coordinated communication. “We kept FedEx pretty busy,” quips Ray. As a result, his firm’s first brush with composite materials was a good one, with valuable lessons learned about fabrication, form possibilities, textures and material variations. Gardiner confirms that S27 was highly adaptable as it worked with composites and learned quickly what the material could and could not do. “The architects were professional, creative and supportive,” Gardiner reports. “They were the key player in this project. They really drove materials use,” he concludes.

As CT went to press, a construction crew was finishing the pavilion’s interior. Two-thirds of the structure will soon be used by Greyhound bus line for ticket sales and information; one-third will house a retail outlet for Washington, D.C.’s Cultural Tourism agency. And bus travelers? They’ll no doubt see the visually arresting pavilion as a familiar sign that they’ve arrived—or are about to depart. [CT]

Editor-in-Chief

Jeff Sloan, CT’s editor-in-chief, has been engaged in plastics- and composites-industry journalism for more than 20 years. jeff@compositesworld.com
Beautiful and aesthetically pleasing, marble has been used for millennia in architecture. Over hundreds of years, the use of marble in building construction evolved from massive load-bearing walls of solid stone to thin stone façades fastened to a building’s superstructure during the 20th Century. In 1974, when the Standard Oil skyscraper (later renamed the Amoco building) was built in Chicago, Ill., the marble façade panels on half the building soon cracked, bowed outward or sometimes completely detached under the onslaught of the Windy City’s severe freeze-thaw cycles, wind and moisture conditions. The building was eventually renovated and the façade panels were replaced.

The façade’s failure was due to the relatively brittle nature of the thin-cut stone. Since then, a variety of materials — glass fabrics, foam, plywood and honeycomb core — have been employed as a backside reinforcement for marble cladding, but Kunovar & Kamini (Ljubljana, Slovenia), a company with a long tradition in the field of natural stone fabrication, recently adopted trademarked Parabeam 3-D glass fabric, manufactured by Parabeam BV (Helmond, The Netherlands), to reinforce flat marble façades and curved column cladding.

Parabeam 3-D glass fabric is woven from E-glass yarn and consists of two deck layers joined by vertical “piles” (z-axis threads) that are woven into the deck layers to form an integral sandwich structure. Because of its inherent drapability — and unlike flat sandwich materials and plywood — Parabeam reinforcement conforms easily to curved column cladding and requires no heat or pressing equipment during application or installation. Parabeam adheres well to porous marble with epoxy resin, which is hand applied with a roller.

As the fabric absorbs the resin, capillary forces within the piles cause the fabric to rise to a preset height and even out any thickness variations in the marble. Several thicknesses are available, from 3 to 10 mm (0.12 to 0.4 inch), with the thickness dependent on the application. For extra reinforcement, several Parabeam layers can be wet out and stacked.

Kunovar & Kamini reports that the use of Parabeam has reduced marble waste from 30 percent to only 5 percent. “With Parabeam reinforcement, the marble cracks less easily, and when it does crack, it can often be repaired,” says the company. In addition, Parabeam reinforcement permits the use of thinner stone panels, resulting in significant weight reductions. For example, a column measuring 2m by 25m (6.5 ft by 81.25 ft) with a 30-mm/1.2-inch marble cover and a 1-mm/0.4-inch traditional reinforcement, such as plywood, weighs 50 metric tonnes/110,000 lb. Using Parabeam, Kunovar & Kamini was able to shave 1 mm/0.04 inch off the marble thickness, eliminate the plywood and, thus, reduce final column weight by 50 percent. Additionally, the lighter façade requires less robust attachment systems (photo, lower right), which equates to more cost and weight savings. Tests show an overall increase in strength of more than 50 percent with Parabeam, compared to unreinforced marble cladding.
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Natural fiber composite drives

AUTOMOTIVE SUSTAINABILITY

Coir felt greens an EV, improves lives in developing world.

It’s not often that a car, let alone a car part, gets credit for saving a village. But that could be the case with the trunk load floor in Ford Motor Co.’s (Dearborn, Mich.) 2012 model year (MY) Focus Electric, the automaker’s first all-electric vehicle. This composite part is reinforced with coconut (coir) fiber, an agricultural waste product that otherwise has little value: It doesn’t burn easily. It’s unsuitable for livestock feed or bedding. And it’s slow to biodegrade, so it isn’t immediately useful as an agricultural soil amendment. But it is in plentiful supply. In villages from the Tropic of Cancer to the Tropic of Capricorn, it’s piled near coconut-processing facilities because the locals don’t have the resources necessary to rid themselves of husks and shells. That prompted College Station, Texas-based Essentium Materials LLC to find a way to capture this bio-waste, convert it into useful products and, thus, provide additional revenue for farmers in the developing world by offering manufacturers in the developed world sustainably sourced products whose prices are not tied to petroleum feedstocks or fluctuations in the futures markets.

UNUSUALLY USEFUL PROPERTIES

Coir fibers are extracted from a coconut’s outermost husk. “With an average diameter of 250 microns, coir fibers … are much larger than most other natural or synthetic fibers,” notes Ryan Vano, Essentium materials engineer, commercial development. “That means it’s inherently stiffer in bending, like a bundle of straws in cross-section, as well as strong and ductile.” Beyond good flexural modulus, coir also has among the highest lignin content of all the natural fibers, which helps make it flame resistant (important for vehicle interiors), unpalatable to microbes (odor and mildew resistant) and less prone to moisture uptake and swelling than many natural fibers. Moreover, it doesn’t take a lot of energy to dry coir after it’s been wet, which is helpful during extraction and processing prior to baling and shipping. “Another big benefit is its broad availability,” says Vano, pointing out that “50 billion coconuts are grown each year.”

Coir also exhibits consistent properties, regardless of coconut species, country of origin, soil and weather conditions, and time of harvest. This was verified in 2008 by Dr. Walter Bradley and his team of researchers at Baylor University (Waco, Texas), who asked, “How can we simultaneously make commercially viable products, help impoverished people and be better stewards of our planet’s resources?” The answer led to the formation of Whole Tree Inc., which, as it grew, was renamed Natural Composites Inc. and then was acquired this year by Essentium.

Essentium works in the Philippines with local partners to extract fiber near the original food-processing plants where coconut milk and meat were previously removed from coconut husks and shells. Essentium has its own processing plant in Indonesia.

The fibers are separated from the husk and other components by what’s described as a patent-pending, “mostly mechanical” process in which no chemicals are used. Then the fibers are processed and packed into shipping containers for a trip to the other side of the world where one of several nonwovens partners turns them into felt.

Its benefits notwithstanding, coconut fiber can’t be used alone. The stiff fiber resists entanglement even in the x and y axes, let alone the z axis. To promote entanglement, the coir fiber is commingled with thermoplastic polypropylene (PP) fiber, sourced from postindustrial recyclate (PIR) and supplied by Drake Extrusions Inc. (Martinsville, Va.). The fibers are blended in a 50/50 ratio, then carded and needled into felt, which is shipped in roll-stock form to the suppliers who make finished products.
**GREENING A GREEN VEHICLE**

Although she no longer recalls which company initially approached the other, Ford's Elizabeth Johnston, product development engineer, Advanced Green Projects, recalls, "We had started to work with the coconut fiber and had realized how many great properties it has. That alone would have made it an interesting material to study. However, when you added in the social context, it just seemed like Essentium Materials and its products really encompassed so many of the things that are important to Ford." Because Essentium had first targeted trunk liners, that became the initial direction of the Ford project, too. "We conducted the same kind of testing we'd do on a traditional material used on trunk trim — looking for issues like odor and moisture absorption," recalls Gian Carlo Morlet Ugalde, Ford release engineer. "When the Focus Electric ... load floor was suggested, we all jumped on it. We knew that using a natural material on an all-electric vehicle was a great fit." This model's low volumes were a plus because becoming an approved automotive supplier is neither a quick nor easy task, and a higher-volume platform, even a gasoline-powered Focus, could have been overwhelming for a start-up organization like Essentium.

**ENGINEERING CHALLENGE:**
Find a semistructural use for a new felt core/reinforcement on an electric vehicle at volumes that enable a start-up supplier to come up to speed.

**DESIGN SOLUTION:**
Create a needled felt of commingled coconut and recycled-PP fibers for incorporation into a bonded trunk-area load floor.

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**FORD FOCUS ELECTRIC**

**BEV LOAD FLOOR**

![Diagram of Ford Focus Electric BEV load floor with materials and labels](Image)

**Illustration | Karl Reque**
The Focus Electric’s load floor hides the battery pack at the front of the trunk by covering the space between the batteries and the trunk opening, and it provides a level surface on which to store items. Through a small door in the load floor, it permits owners to access the vehicle’s charging cable. And it helps prevent the transmission of road noise to the vehicle’s cabin.

After the program target was identified, testing went into high gear. “We have some pretty aggressive requirements for load floors to meet,” explains Bhavani Thota, Ford interior trim supervisor. “In use, the floor has to lie flat and fit well. While the body’s sheet metal supports it pretty well around the periphery, the center section of the load floor is unsupported. Nonetheless, it has to carry loads without sagging.” To confirm this, Ford engineers placed two 50-lb/23-kg sandbags next to each other in the center of the span and raised the temperature to 100°C (212°F) to check for deflection.

“The rear decklid glass puts a lot of sunload on anything in the trunk, so heat can be an issue and we do extensive testing on these parts,” Thota adds, noting that in another test, two sandbags are stacked on top of each other in the center of the peripherally supported load floor, which is then subjected to five days of extreme temperature cycling — from 100°C to -30°C (212°F to -22°F). “We look for creep and delamination,” he explains. “We measure deflection during the test and then 24 hours after the test is complete to make sure there is no permanent set. The floor must return to its original shape ±5 mm [0.20 inch].” Additional testing evaluates deflection under a distributed load (that is, with separate loads in all four corners and in the center). To check abrasion and mar resistance, suitcases are dragged across the carpet face of the part. The coconut fiber-reinforced load floor passed with flying colors.

Notably, the load floor in question was not originally designed to use the coconut fiber pad. Rather, the initial plan was to use a cotton shoddy material containing some bio-component polyester resin plus recycled cotton fibers. Because the shoddy also is pressed into a mat before it’s incorporated into the final part, the switch was resin plus recycled cotton fibers. Because the shoddy also is pressed into a coconut fiber pad. Rather, the initial plan was to use a sprayed layer of styrenated block copolymer (SBC) hot-melt pressure-sensitive adhesive (PSA) from Bostik Inc. (Wauwatosa, Wis.). Then more adhesive is added, along with a layer of pressboard/press laminate that is also made with reclaimed fibers. Next comes more adhesive and the coir/PP felt. Finally another layer of adhesive is applied, followed by the B surface, a nonwoven scrim. The adhesive primarily tacks the layers together prior to die cutting.

The density and thickness are varied across the part by adding or eliminating pressboard, depending on whether more stiffness is needed or the part needs to be thinner. The porous lofted coir core is not compressed, so it provides noise, vibration and harshness (NVH) functionality.

A cable access opening is cut in the center (pressboard is left out of the stack around its perimeter), and in a postfinishing operation, a small door with a molded-in finger pull is mounted over the opening. The door is produced separately, in much the same configuration, but hardboard replaces pressboard for greater stiffness and durability. The door is mounted flush with the load floor surface so it won’t be torn off when heavy objects are pulled across the floor. The nominal floor/door wall thickness is 10 to 11 mm (0.39 to 0.43 inch).

DOOR TO THE FUTURE

In production for two years, the floor has worked well on the roughly 600 Focus Electric units sold in Europe and about 3,000 more sold in North America. And it’s been a good learning experience for all parties. “We don’t want this technology to be a ‘one-hit wonder,’” says Rose Petrella, Ford product development analyst, “so we keep evaluating it to see where else it can be used.” In fact, a second application already made its debut on last year’s Ford F-250 pickups — a coconut shell/bio-recycled structural guard injection molded in a thermoplastic elastomer (TPE). And both Ford and Essentium hint at another composite application to come in 2014. | CT |
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